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ABSTRACT

This competency-based curriculum for energy-efficient building construction is intended to educate students in the importance of conserving energy and to provide for developing skills needed in the application of energy-saving techniques that result in energy-efficient buildings. Each of the eight units is based on one to five competencies. For each one a student competency sheet is provided with the following information: competency statement, learning steps, a list of learning activities, and a suggested student evaluation. Where appropriate, information sheets and study guides (with answer keys) are provided to enable the students to complete the learning activities. Unit topics are (1) plan selection; (2) site selection; (3) foundation construction; (4) floors, walls, and ceilings; (5) roof and attic ventilation; (6) heating and cooling equipment; (7) passive solar fundamentals; and (8) maintenance. An appendix contains 23 tables that are referenced in the curriculum. A bibliography is also provided. (Some reading assignments in other textbooks and references are required. Sources of some additional reference materials--print and nonprint--are cited.) (YLB)

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Competency Based Education Curriculum

for

Energy Efficient

Building Construction

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PREFACE

It is with great pleasure that we bring you another West Virginia competency based education (CBE) curriculum. This competency based Energy Efficient Building Construction curriculum was developed under contract by United Career Center for West Virginia. The effort was coordinated by staff of the West Virginia Bureau of Vocational, Technical and Adult Education.

This document is organized into eight units. The units and the competencies for each are given in the table of contents. Each student competency sheet includes the unit, competency, learning steps, learning activities and evaluation.

A special thanks to Mr. John Cole, Project Director, for his effort and many hours he put into this project. Additional copies of this curriculum are available from:

West Virginia Vocational Curriculum Laboratory
Cedar Lakes Conference Center
Ripley, West Virginia 25271
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in-state toll free 1-800-642-2670

I trust this material will be of assistance in your program. Any suggestions you may have for improving this curriculum may be sent to the Vocational Curriculum Laboratory. Through this feedback we plan to continually update and revise our materials.

VOCATIONAL, TECHNICAL AND ADULT EDUCATION

Clarence E. Burdette,
Assistant State Superintendent of Schools

ACKNOWLEDGEMENTS

The Energy Efficient Construction Curriculum was developed through the sponsorship of the Bureau of Vocational, Technical, and Adult Education.

The curriculum was prepared by the Energy Committee of the United Career Center. Review and inputs were provided by builders, suppliers, and developers.

Throughout the development of the curriculum, direction and assistance was provided by Larry Froehlich of the Bureau of Vocational, Teechnical and Adult Education.

The principal authors of the curriculum are: John Cole, I.M.C. Coordinator and Project Director; Randy Glenn, Carpentry Instructor; Ronald Marino, Electricity Instructor, and Dan Glover, Supportive Services.

Finally, special thanks go to Robert Lykens, Director, for his encouragement and support. Izetta Succurro, Business & Office Instructor for processing and keeping the information in order, Gretta Gregory and Karen Stutler for typing the document.

INTRODUCTION

There are many factors which enter into any decision about efficient energy use and economic feasibility in the design, construction and operation of a building. Inexpensive energy has allowed us to design and construct buildings with little or no regard for the local climate, the nature of materials, or the efficiency of the support systems installed. To some extent, we have even ignored the comfort and health of the persons living and working in these structures by excessive use of artificial heating, cooling and lighting. We have become controlled by our excesses rather than by our senses. We have in most cases consumed much more energy than was necessary.

The shortages and, therefore, higher costs of our traditional fuels are causing us to take a careful look at the way we design, construct, and operate our living and working spaces. We can no longer ignore the concepts of conservation, innovation, and increased efficiency.

Over the past few years passive solar design has enjoyed a growing audience of enthusiasts working in a variety of areas, mostly on the periphery of the housing industry. Parallel to the development of the technical foundations of passive solar design is a growing interest among builders and designers in incorporating passive concepts into their standard building practices.

This training program will consider ways in which building designs, construction methods, and operating systems can be chosen so that energy can be used more effectively and with less expense.

It is hoped that this training program will help educate students in the importance of conserving energy, and to provide for developing skills needed in the application of energy-saving techniques that result in energy-efficient buildings.

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UNIT I
PLAN SELECTION

COMPETENCY 1 Selecting plans for energy efficient shape.

LEARNING STEPS:

1. Calculate areas of planes A=LXW
2. Calculate volumes V=LXW x H
3. Define ratio
4. Determine volume to surface area ratio

LEARNING ACTIVITIES:

1. Attend teacher presentation on area, volume and ratio calculations.
2. Read Information Sheet I-1-1. "Design Features that Affect Energy Use".
3. Refer to Unit 20, Principles of Surface Measurement and Principles of Volume Measure. pages 101 - 127 in Basic Mathematics Simplified.
4. Calculate exposed wall surface, ceiling surface, and floor surface areas on a house plan.
5. On a house plan calculate volume of living areas.
6. Compare as a ratio volume to surface area or provided house plan.

EVALUATION:

Given three house plans, calculate volume to surface ratio and rank in order of best energy efficient shape for your geographic area.

DESIGN FEATURES THAT AFFECT ENERGY USE

Several design features of a building need to be considered to make it energy-saving. The design features considered here include:

Shape and Volume

The square floor area of a building affects the cost--both initial outlay and continuing maintenance and operation. Larger buildings require more construction materials and a larger capacity for heating and cooling equipment than smaller buildings, as well as more fuel to maintain a comfort zone within the building.

The optimum shape is one which has minimal heat gain in summer and minimal heat loss in winter. Therefore, the form of a building depends upon the climatic region. Three factors help determine optimum shape: (1) volume-to-surface ratio; (2) solar exposure; and (3) potential for insulation. The volume-to-surface ratio of homes is important, but cannot be considered alone in determining the shape. It might appear that a cubicle house would have the least heat loss and gain because it is compact, but this is not the case. The optimum shape for thermal impact for every climate is a rectangle with differing degrees of elongation along the east-west direction. Figure 4 illustrates the optimum range for each climate as determined by Olgyay. However, Olgyay did not consider the potential for insulation.

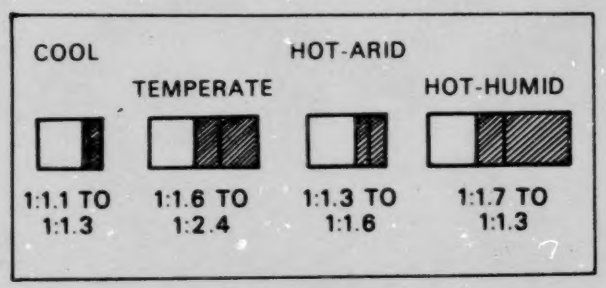

FIGURE 4. Optimum Building Shapes for Climate Zones (Ratio of width to Length).

The National Association of Home Builders (NAHB) has shown that the potential for insulation is a very important factor in determining the optimum shape of a home for thermal efficiency. A two-story house may not have any less heat loss or gain than a one-story house of the same square area. The fact that ceiling areas are more effectively insulated than walls makes the one-story house equally as efficient as a two-story house.

The volume effect (as the volume of a cube increases, its volume-to-surface area ratio increases) plays a more important role in larger buildings such as apartment houses or office buildings. An interior space may have a lower heating and cooling load because it has less surface exposed to the weather. Figure 5 illustrates volume-to-surface areas.

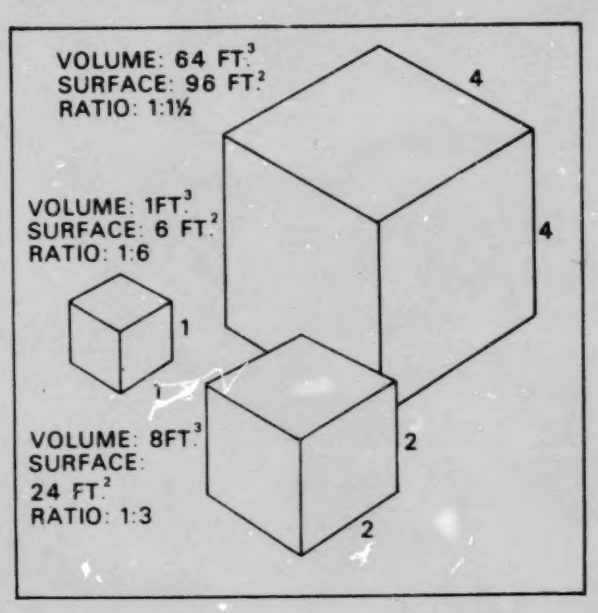

FIGURE 5. The surface area exposed to outside affects energy use. Note energy loss is reduced in both cold and hot-arid climates by "square" designs.

UNIT I

COMPETENCY 2: Select other structural design features that allow for energy conservation.

LEARNING STEPS:

1. Determine potential for insulation in foundations, roofs, walls, windows, and doors.

2. Compare potential for insulation to acceptable insulation requirements for your area.

3. Select design features that will allow for energy efficient foundations, roofs, walls, windows and doors.

LEARNING ACTIVITIES:

1. Attend teacher presentation on structural design and insulation specifications for your area.

2. Read information sheet. "Energy Efficient Structural Design features" I-2-1.

3. Read information sheet "Effect of Design" I-2-2.

4. Draw a sketch of an energy efficient building and indentify reasons why it is efficient.

5. Answer questions on study guide.

EVALUATION:

Given a house plan determine insulation material requirements for Energy Efficient Construction.

UNIT I

STUDENT STUDY GUIDE I-2-1

Circle the letter(s) that represent the correct answer(s), unless instructed otherwise.

1. An energy efficient home or building is one that is designed to provide space and comfort to its occupants at reasonable cost and without harmful effects on the environment.

   a. True. b. False.

2. The shape of a building has no influence on the energy requirements.

   a. True. b. False.

3. Which three factors influence the shape of a building with regard to energy use?

   a. True. b. False.

4. Flat roofs may be used for:

   a. Retaining rain water and/or snow for insulation.
   b. Shedding snow in winter. c. Attic storage.

5. Pitched roofs provide for attics which need no insulation.

   a. True. b. False.

6. Roof overhang should provide for:

   a. Window shading in summer. b. Window shading in winter.
   c. Shedding snow.

7. Walls should be designed to:

   a. Reduce heat transfer. b. Provide a vapor barrier.
   c. Protect the interior from the weather.
   d. All of the above.

8. Heat transfer through windows is:

   a. Less than through walls. b. Greater than through walls

9 Match the following recommendations for window size and locations

a. Large. b. Small c. Medium d. None.

___ East. ___ West. ___North. ___South.

10. When practical, doors should be placed on the

a. South.
b. East.
c. North.

11. The comfort range in temperature when designing buildings is

a. 40°F-90°F. b. 60°F-85°F. c. 80°F-90°F.

12. Humidity affects energy requirements for comfort. More heat is required when the air is

a. Hot and humid.
b. Cool and humid.
c. Cool and dry.

13. Space design for energy efficiency requires:
a. Smaller heated and cooled areas.
b. Larger heated and cooled areas.
c. Space is not important.

14. Building design for energy efficiency is:
a. Relatively important.
b. Very important
c. Not important

15. Initial cost of energy efficient structures and compared to conventional design is:
a. Much higher.
b. Very little higher.
c. About the same.

UNIT I
STUDENT GUIDE I-2

ANSWER KEY

1 A

2 B

3 A B C

4 A

5. B

6. A

7. D

8. B

9. East-C West-B North-D South-A

10. A

11. B

12. B

13. A

14. B

15. B

Foundations

Footings and foundations connect a building to the ground. The masonry or concrete of which most foundations are made has very poor thermal resistance qualities, thus allowing heat to flow into the ground below. The type of foundation used will determine the location and type of insulation required. The type and amount of insulation to use on various foundations will be explained in "Part D. What Type and How Much Insulation to Use." Various types of foundations and their functions are discussed and illustrated here.

(1) ISOLATED PIERS AND POST FOOTINGS are the simplest and usually the cheapest (Figure 6). In cold climates, the exposed underside of the floor must be insulated. In warm climates, insulation provides ventilation and separation from ground moisture.

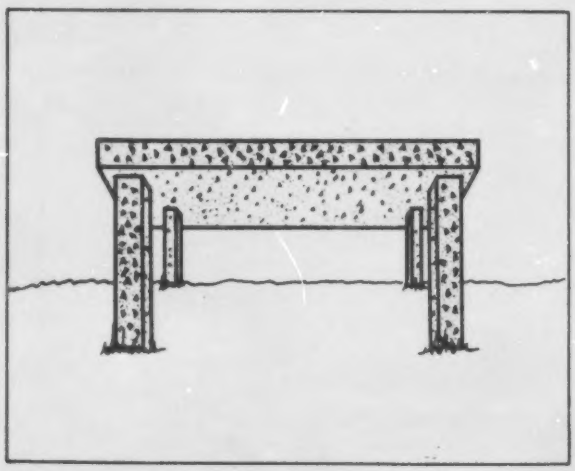

FIGURE 6. Foundation on piers.

(2) CONTINUOUS FOOTINGS AND FOUNDATION WALLS are the most expensive and complicated (Figure 7). They allow for a warmer floor and can provide a basement for a heating system, working space and storage. Unheated areas require an insulated floor above, heated areas, an insulated wall and slab perimeter.

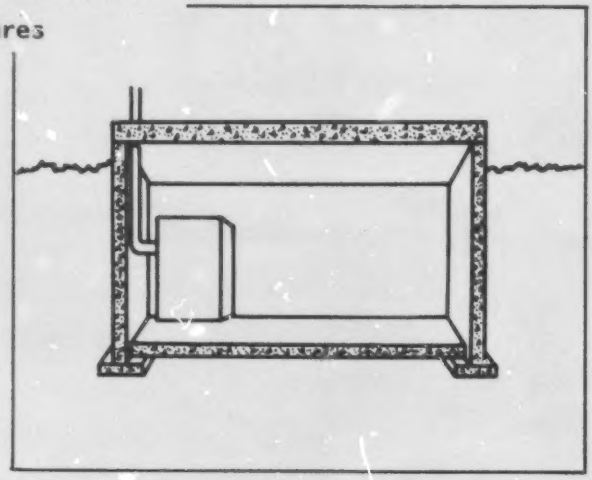

FIGURE 7. Enclosed basement.

(3) SLAB arrangements are simple and quick to build (Figure 8). In cold climates, they require a deep layer of well-drained soil to act as support and insulation under the slab or vertically on the edge of frost walls. Slab foundations are best on flat sites and well-drained soils.

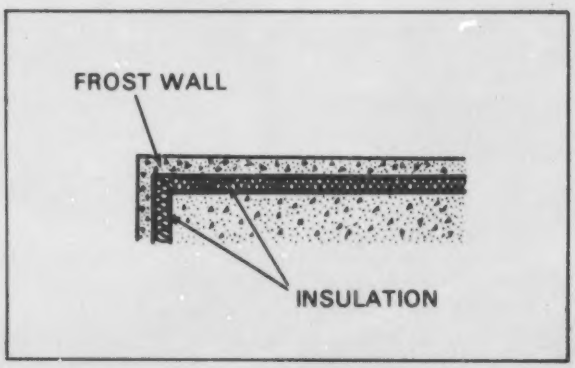

FIGURE 8. Slab foundations reduce energy loss through floors.

Roofs

Roofs are either (1) flat or (2) pitched.

(1) FLAT ROOFS are useful for catching and retaining rainwater in arid climates, the sun's rays on solar panels or snow for added insulation in cold climates (Figure 9). The space may also be usable for decks or gardens. However, flat roofs do not readily shed water. If you are not using it for one of the above reasons, do not consider one. The energy saving is not sufficient.

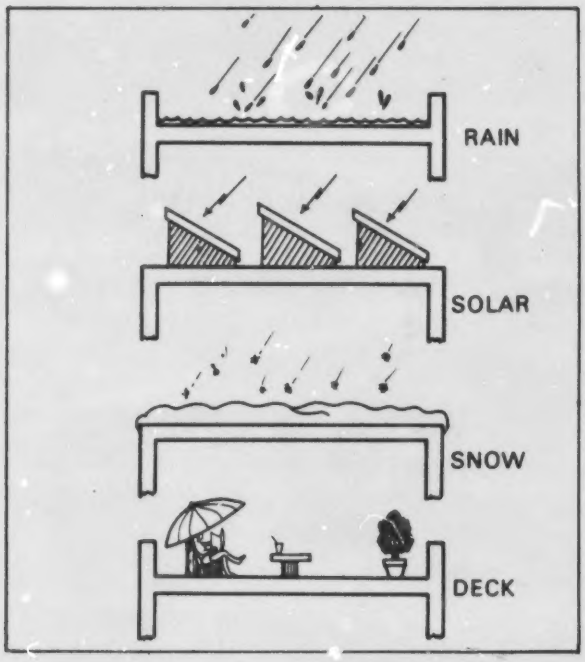

FIGURE 9. Applications of flat roofs.

(2) PITCHED ROOFS which shed water best are termed low-pitched or steep-pitched (Figure 10). Steep-pitched roofs are good for shedding snow and may also enclose space as a diagonal wall.

In structures like A-frames and domes, the surface forms both the roof and the wall (Figure 11).

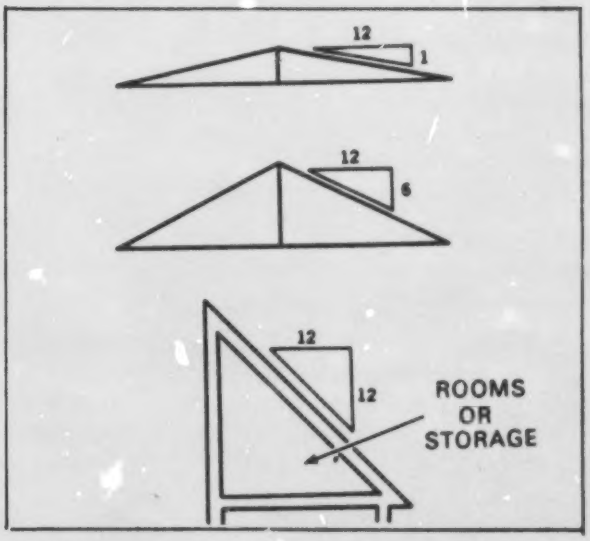

FIGURE 10. The pitch of your roof may be important to energy efficiency.

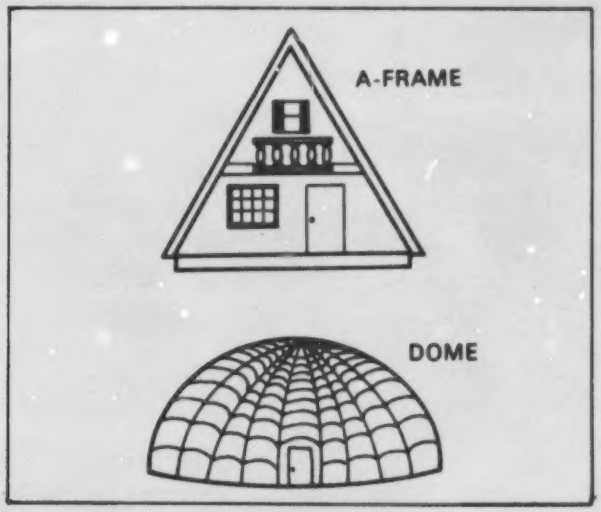

FIGURE 11. A-frame and dome roofs must be well-insulated to conserve energy.

(a) A low-pitched roof (between 1:12 and 6:12) will shed water, and the lower pitches will retain snow for insulation. The inside area can provide additional space as a sloped ceiling.

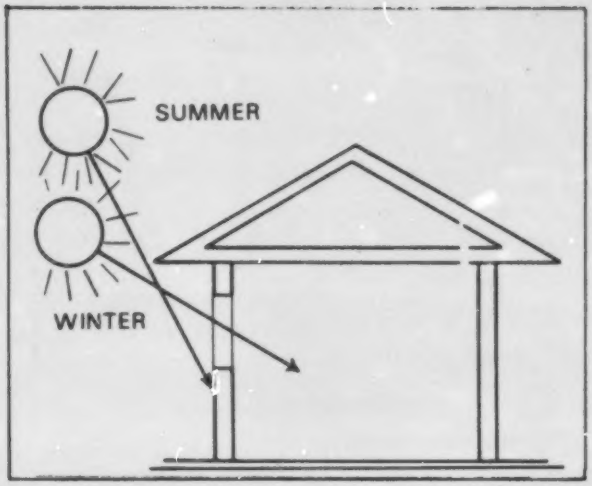

FIGURE 12. Roof overhang can be advantageous in saving energy.

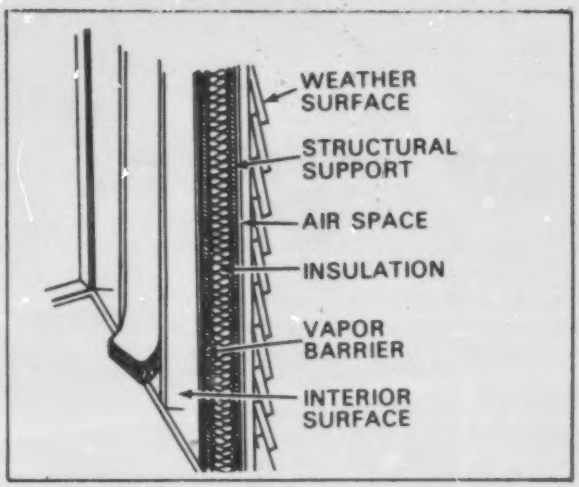

FIGURE 13. Wall should be designed to retain heat in winter and to prevent solar heat gain in summer.

(b) A steep-pitched roof (6:12 to 12:12 and above) will shed almost everything. That's the reason for the pitch. Since it requires more material to form the larger surface, it is more expensive. These roofs can provide additional rooms or storage. Steep pitches (45°) are also good for placing solar collectors in northern climates.

(3) ROOF OVERHANG is a common method of protecting windows and walls from summer sun and allowing winter sun to enter. Overhands can also shield entrances (Figure 12).

(4) ROOF COLOR is also important. ASHRAE and HUD studies indicate that light-colored roofing material is best; however, ceiling or roof insulation greatly affects the interior heating and cooling load. A dark-colored roof may only slightly reduce the heating load while substantially increasing the cooling load in southern climates.

Walls

A well-designed wall will serve two major functions: (1) retain heat inside the building and prevent cold air outside from entering; (2) prevent unwanted solar heat gain in summer, which would require energy to remove. Conduction and infiltration through walls can be reduced by using insulation, making walls airtight, and by minimizing the undesirable effects of wind and sun.

Energy-conserving walls will have these elements (Figure 13):

- A weather surface—to shed water and protect the other wall elements from moisture and air infiltration.
- Structural support—to support the wall and other building elements.
- Insulation—to prevent conduction of heat in either direction.
- Air space—to provide ventilation within wall elements and serve as increased insulation.
- A vapor barrier—to prevent moisture from entering the wall and to help prevent infiltration.
- An interior surface—to provide a wearing surface for interior activities and some insulation value.

Additional information on insulation and other materials will follow.

Windows

Although windows and doors allow greater heat loss or gain than walls, they are necessary and can be improved by their location and construction. Eight times as much heat will pass through one unit area of window area as will pass through one unit area of wall area (Figure 14), assuming that the wall is insulated and the window has a storm window.

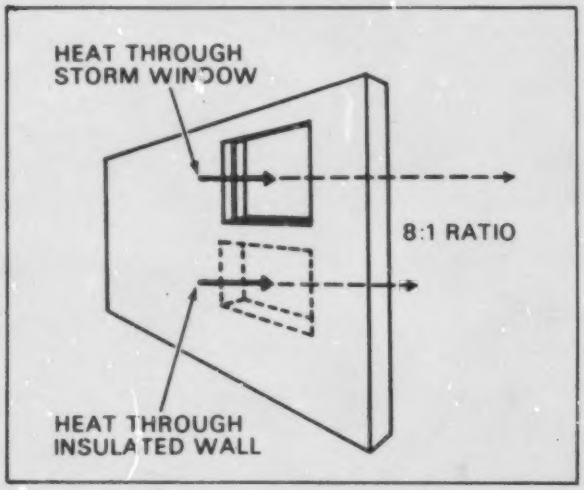

FIGURE 14. Glass is a poor insulator.

Heat loss and gain through windows and doors can be reduced by storm panels, weatherstripping, double-glazing, vestibules, shading devices, and wise placement. The loss of heat through various window constructions will be covered.

Windows can be planned to provide natural light, the benefit of solar heat, natural ventilation, and a view to the outdoors. All of these functions will reduce the need for and cost of energy for these operations (Figure 15).

(1) WINDOWS FOR SOLAR HEAT GAIN (Figure 15).

- The largest windows should face the east-southeast as this is the warmest exposure and causes the least heat loss.
- Small windows on the west or windows with shading devices will help to control the low-lying sun.
- Either no windows or small protected windows on the northwest and north are best.
- Properly designed southern and south-western windows have the best potential for controlling solar heat gain both in cold and warm months.

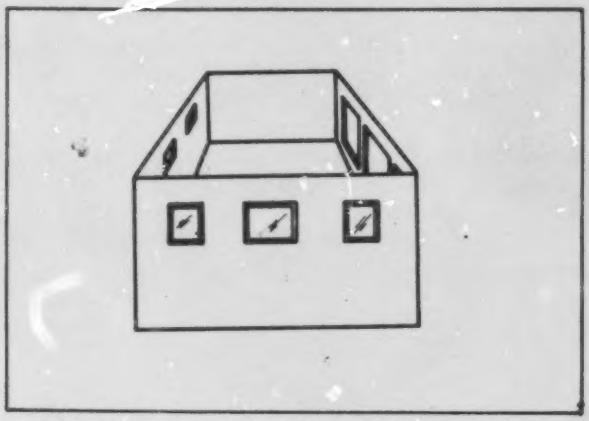

FIGURE 15. Windows can be designed to save energy.

(2) WINDOWS FOR NATURAL VENTILATION:

- Plan window openings for cross-ventilation.
- Air flow openings of the same size for inlets and outlets will provide good ventilation. Larger outlets provide faster air flow.
- Desired air flow can be directed by: (a) a combination of openings, (b) lower wall placement for better cooling, (c) using exterior features to deflect air flow, (d) window deflectors.

(3) WINDOWS FOR NATURAL LIGHTING AND OUTDOOR VIEWS:

- Natural light is available on all exposures--the north being the easiest to control.

- Control east and west exposures with vertical windows.

- Southern exposures offer the most light. Control of the sun angle is best accomplished with horizontal windows placed high on the wall.

- Roof mounted skylights offer good possibilities for lighting interior spaces.

- Window size and placement can be used to provide light for specific areas and to frame specific views.

Doors

We can treat the heat loss through doors about the same as we do windows. The most common method is to add a storm door. A better method is to form an air lock and cut down on drafts by adding a vestibule. When possible, doors should be placed on the south or southeast. If doors are in an exposed location, overhangs, baffles or plantings can protect against the wind. Doors can also provide a degree of light and ventilation if properly chosen and placed.

Even a 5.1 cm (2 in) solid door with wood storm door has a heat loss 3.5 times greater than a typical wall.

INFORMATION SHEET I-2-2

EFFECT OF DESIGN

The shape of a building also has an effect on the amount of energy used. Generally, a rectangular house oriented east and west will use the least amount of energy (Figure 81).

Design should allow for exposure of windows to sun in winter and shade in summer (Figure 82). Shades may be used effectively.

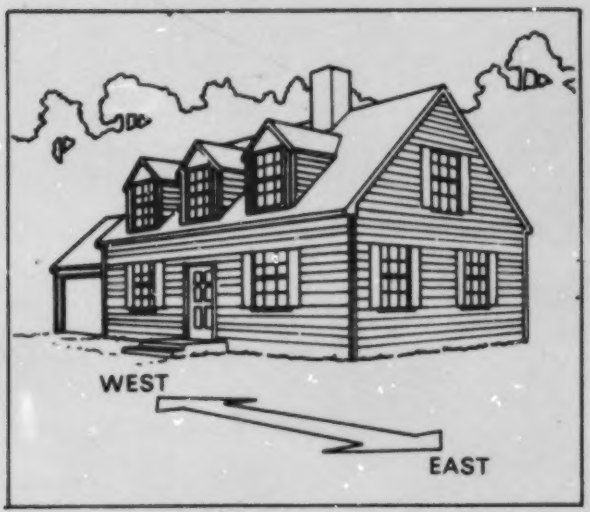

FIGURE 81. Rectangular houses oriented toward east and west generally use less energy year round.

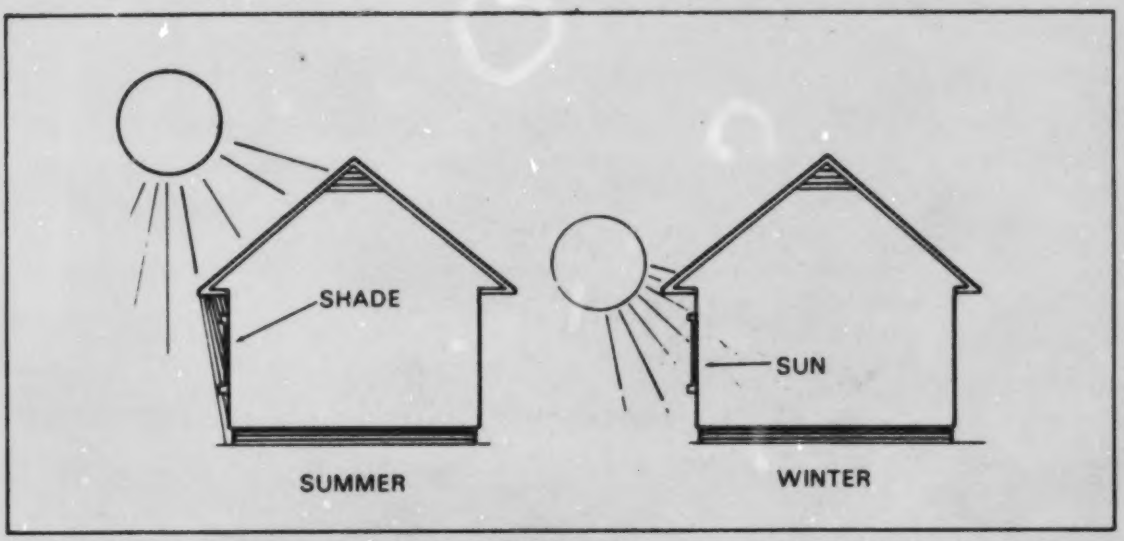

FIGURE 82. Windows should be exposed to sun in winter and should be shaded during summer.

Many factors are taken into consideration, including the orientation of the house, slope of the roof, hours of sunshine, prevailing winds and site latitude.

Mechanical equipment should not impose large loads on the utility system during peak periods. The selection of oversized equipment should be avoided. In commercial buildings, the most significant features include the use of insulation, proper fenestration, control of ventilation, levels of illumination, orientation of the building, and the exposed surface area.

It has been proven that construction costs do not have to be greatly affected in either residential or commercial buildings in order to save energy. An example of this fact in commercial buildings is in the General Service Administration Building in New England. Energy usage is cut between 30-50% by the use of good design. The price came to $50.10 per square foot in comparison with the average cost of $50.00 per square foot for similar construction in that area.

STUDY GUIDE I-2

Circle the letter(s) that represent the correct answer(s), unless instructed otherwise.

1. An energy efficient home or building is one that is designed to provide space and comfort to its occupants at reasonable cost and without harmful effects on the environment.

   a. True.
   b. False.

2. The shape of a building has no influence on the energy requirements.

   a. True.
   b. False.

3. Which three factors influence the shape of a building with regard to energy use?

   a. Volume to surface ratio.
   b. Solar exposure.
   c. Potential for insulation.
   d. Size of family.

4. Flat roofs may be used for:

   a. Retaining rain water and/or snow for insulation.
   b. Shedding snow in winter.
   c. Attic storage.

5. Pitched roofs provide for attics which need no insulation.

   a. True.
   b. False.

6. Roof overhang should provide for:

   a. Window shading in summer.
   b. Window shading in winter.
   c. Shedding snow.

7. Walls should be designed to:

   a. Reduce heat transfer.
   b. Provide a vapor barrier.
   c. Protect the interior from the weather.
   d. All of the above.

8. Heat transfer through windows is:

   a. Less than through walls.
   b. Greater than through walls.

9. Match the following recommendations for window size and locations:

   a. Large.
   b. Small.
   c. Medium.
   d. None.

   __East.
   __West.
   __North.
   __South.

10. When practical, doors should be placed on the:

    a. South.
    b. East.
    c. North.

11. The comfort range in temperature when designing buildings is:

    a. 40°F-90°F.
    b. 60°F-85°F.
    c. 80°F-90°F.

12. Humidity affects energy requirements for comfort. More heat is required when the air is:

    a. Hot and humid.
    b. Cool and humid.
    c. Cool and dry.

13. Space design for energy efficiency requires:

    a. Smaller heated and cooled areas.
    b. Larger heated and cooled areas.
    c. Space is not important.

14. Building design for energy efficiency is:

    a. Relatively important.
    b. Very important.
    c. Not important.

15. Initial cost of energy efficient structures and compared to conventional design is:

    a. Much higher.
    b. Very little higher.
    c. About the same.

UNIT I
STUDENT GUIDE I-2

ANSWER KEY

1. A
2. B
3. A,B,C
4. B
5. A
6. D
7. B
8. East-C; West-B; North-D; South-A
9. A
10. B
11. B
12. A
13. B
14. B

UNIT I
PLAN SELECTION

COMPETENCY 3: Understanding the terms used to measure energy in buildings.

LEARNING STEPS:

1. Identify the energy terms for measuring heat flow.
2. Identify the energy terms for measuring heat conductivity.
3. Identify other energy related terms.
4. Study these terms.
5. Ask for further explanations and information where necessary.

LEARNING ACTIVITIES:

1. Attend a teacher led discussion on the terms used to measure energy in buildings.
2. Read Information Sheet I-3-1 "Terms Used To Measure Energy in Buildings."
3. Write in your own words the definitions for the following terms:

   a. infiltration
   b. ventilation
   c. heating degree day
   d. relative humidity
   e. confort zone

EVALUATION: Complete Evaluation I-3-1

INFORMATION SHEET I-3-1

Terms Used to Measure Energy in Buildings

There are several terms used in measuring energy in buildings. Most of them are familiar. From your study of this section, you will be able to list and define these terms. They are described as follows:

1. Terms for Measuring Heat Flow.
2. Terms for Measuring Heat Conductivity.
3. Other Terms.

1. TERMS FOR MEASURING HEAT FLOW

Terms for measuring and calculating heat flow are as follows:

a. Unit of Heat (Btu).
b. Rate of Heat Flow (Btu/hr) or (q).
c. Heat Flow by Conduction (q_c).
d. Heat Flow by Infiltration (q_i).
e. Heat Flow by Radiation (q_{cr}).

a. Unit of Heat (Btu)

The British Thermal Unit (Btu) is the unseen quantity of heat that seeks an equilibrium of temperature between two temperature differences. By definition, it is the amount of heat energy required to raise the temperature of one pound of water one degree F (Figure 1). The Btu is the term for measuring heat.

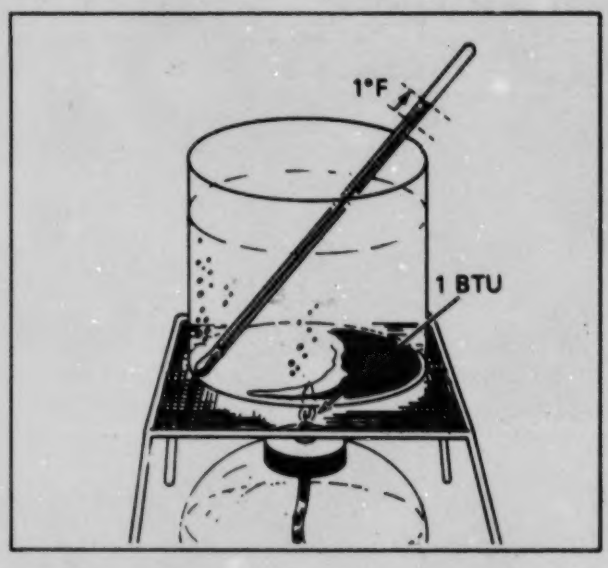

FIGURE 1. A Btu is the amount of heat energy required to raise the temperature of one pound of water one degree F.

For example, note the following equivalents:

1 Btu = 1 wood match
3,413 Btu = 1 kilowatt hour
1,000 Btu = 1 cu. ft. natural gas
140,000 Btu = 1 gal. fuel oil
13,000 Btu = 1 lb. coal

b. Rate of Heat Flow (Btu/hr) or (q)

Heat flow (q) is the movement of thermal energy from a point of high temperature to a point of lower temperature. It is measured in Btu/hour.

c. Heat Flow by Conduction (q_c).

Conduction (q_c) is the flow of heat energy through solid materials by means of molecular vibration. It is measured in Btu/hr.

d. Heat Flow by Infiltration (q_i).

Infiltration heat loss (q_i) is the heat lost by a building through infiltration air exchange. This is usually through cracks and crevices and opening of doors and windows. This is measured in Btu/hr.

e. Heat Flow by Radiation (q_{cr}).

Radiation is usually the effect of sunlight on a building. It is the flow of heat energy from a warm body to a cooler body by means of electromagnetic energy.

Solar radiation is measured in Langleys or Btu. One Langley is equal to 3.687 Btu per square foot per day.

Solar radiation varies with latitude, seasons and weather. For example, a cloud cover will reduce the amount of solar radiation.

2. TERMS FOR MEASURING HEAT CONDUCTIVITY

How much heat a material will allow to transfer is measured in several terms:

a. Thermal Conductivity (k-Value).
b. Thermal Conductance (C-Value).
c. Coefficient of Heat Transfer (U-Value).
d. Thermal Resistance (R-Value).

a. Thermal Conductivity (k-Value)

Thermal conductivity is a scientific measurement of the rate of heat flow through a given substance. It is determined in a laboratory. It is the amount of heat in Btu/hr that will flow through a substance that is 1 foot square, 1 inch thick when there is a temperature difference of 1° between sides (Figure 2).

The thermal conductance (C) varies with thickness of the material.

The lower the k-Value, the higher the insulation value. This value is not used for building materials because it is limited to 1" thickness and will vary at different temperatures.

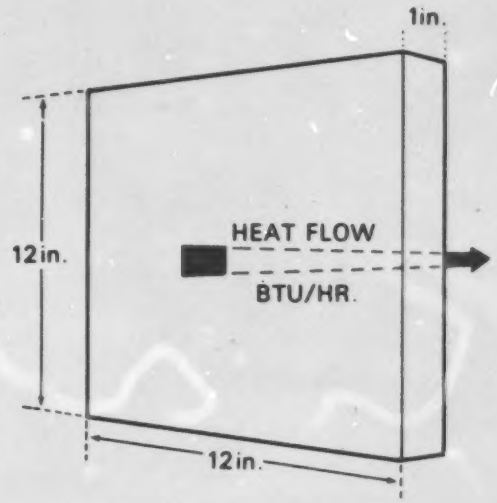

FIGURE 2. The thermal conductivity of a substance is the amount of heat that will transfer through 1 square foot, 1 inch thick when there is a temperature difference of 1°F.

b. Thermal Conductance (C-Value)

The thermal conductance of a material is similar to k-Value, but it may be based on a specified thickness rather than 1 inch (Figure 3). Therefore, C-Value is the amount of heat in Btu/hr that will flow through a material that is 1 foot square, and any specified thickness for each degree F difference in temperature. Neither is it necessary for the material to be homogeneous or solid.

The lower the C-Value, the better the insulation.

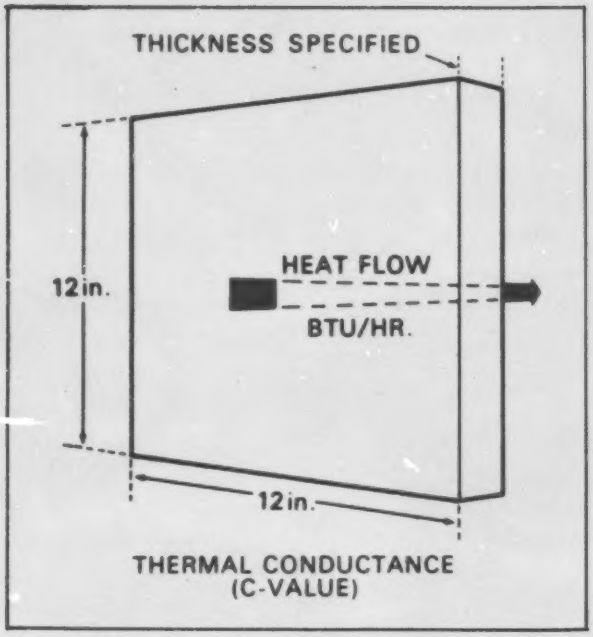

FIGURE 3. Thermal conductance.

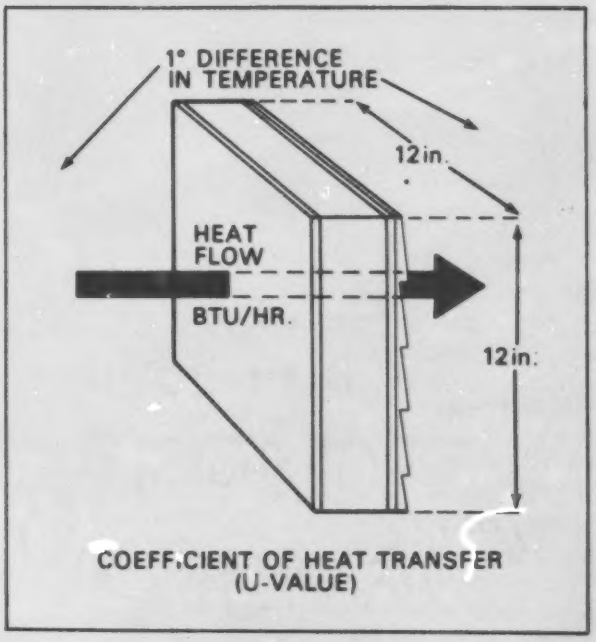

FIGURE 4. U-Value of a wall section.

c. Coefficient of Heat Transfer (U-Value)

The overall coefficient of heat transfer is more meaningful than C-Value when determining the insulating value of a building section. It includes all the materials and air space in a combined wall section. Therefore, U-Values are used to determine heat losses and gains in buildings.

The U-Value is defined as the amount of heat in Btu/hr that will transfer through 1 square foot of wall section in 1 hour for each degree F difference between sides (Figure 4).

As with C-Value, the lower the U-Value the better the insulation quality.

d. Thermal Resistance (R-Value)

The thermal resistance (R-Value) of a material is the term most commonly used for measuring insulation values. One reason, it is easier to understand because as the R-Value increases the value of the insulation increases. The unit for R-Value is hours x unit area x difference in degrees per Btu, $t \times ft^2 \times hr/Btu$.

R-Value is a measure of the resistance to heat flow, not rate of heat flow (Figure 5). To find R-Value from the C-Value and U-Value,

$$R = \frac{1}{C} \text{ and } R = \frac{1}{U}$$

To find the R-Value from the k-Value,

$$R = \frac{\text{thickness of homogenous material}}{\text{conductivity of material}}$$

R-Values are also used to calculate heat transfer in buildings. Most insulating materials are rated in R-Values.

3. OTHER TERMS

Other terms you will be using are defined as follows:

a. Infiltration

Infiltration is the movement of outside air into or out of a building through unplanned openings in components such as cracks around windows.

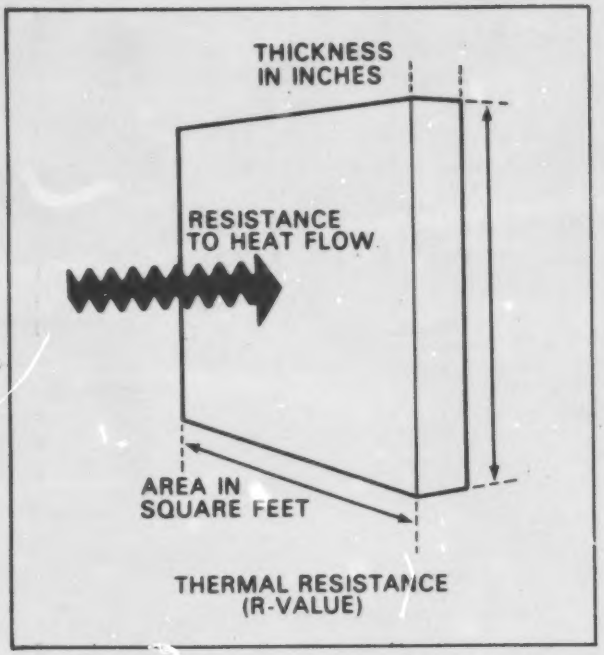

FIGURE 5. The higher the R-Value, the better the insulation.

b. Ventilation

Ventilation is the introduction of outside air through the heating or cooling system or by means of ventilation fans.

c. Fenestration

Fenestration is the glass or other transparent area of the building through which solar radiation can be transmitted.

d. Kilowatt Hour

Kilowatt hour is a measurement of electric energy.

1 kilowatt hour = 3,413 Btu

e. Inside Design Temperature

Inside design temperature is the dry-bulb temperature that is most comfortable. While the most comfortable temperature will vary with humidity, the following temperatures are required by ASHRAE standard 90-75:

- Winter inside design temperature - 72°F
- Summer inside design temperature - 78°F

Note: These temperatures all may be changed in order to conserve more energy. For example,

- winter - 68°F.
- summer - 80°F.

f. Outside Design Temperature

Outside design temperature is based on average extreme temperatures in a certain locality during a "specified" season. These have been computed by ASHRAE. They are listed for different cities in Cooling and Heating Load Calculation Manual, ASHRAE, 1979. Table II gives excerpts from the table.

Outside design temperatures are given for both winter and summer conditions.

g. Heating Degree Day

A heating degree-day is a term used to describe cold climatic conditions in a certain area for computing heating loads. A heating degree-day is the average number of degrees outside temperature is below 65° for a day. The annual degree days are a total of all the degree-days for a year.

For example, the temperature is taken every hour for 24 hours and the average is recorded at 60°F. The heating degree-day is 65°F - 60°F = 5°F. Most of the heating degree days will occur during December, January and February.

h. Cooling Degree Day

A cooling degree day is a term used to describe warm climatic conditions in a certain area for computing cooling loads. A cooling degree day is the average number of degrees outside dry-bulb temperature above 75° (70°F in New York and 60°F in Florida). Multiply the degrees below 75°F times number of days to get cooling degree days.

i. Discomfort Index

When figuring air conditioning, a discomfort index is used instead of dry-bulb temperature. Using the discomfort index, a cooling degree-day is the average discomfort index above 60 for a given day.

Discomfort index is computed from both the dry-bulb and wet-bulb temperature (Figure 6).

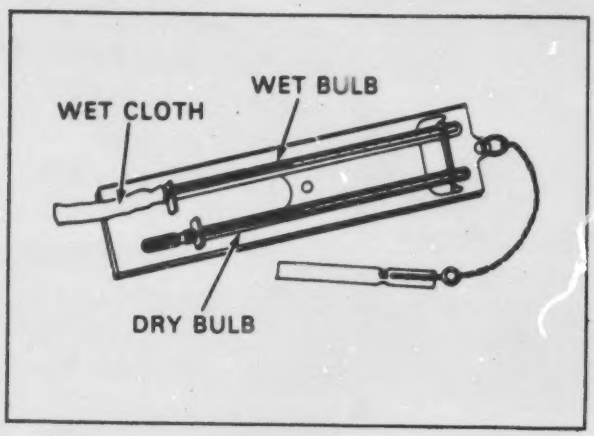

FIGURE 6. Sling psychrometer for measuring wet and dry bulb temperature.

j. Relative Humidity

The relative humidity influences comfort or discomfort. It is the approximate amount of moisture in the air as compared to the maximum amount that could be there at a specific temperature. Relative humidity is determined by taking the readings on a sling psychrometer and referring to a chart designed for the instrument.

k. Comfort Zone

The comfort zone for a person is between 72°F and 80°F with a relative humidity of between 20% and 60%.

The body is more tolerant of higher temperatures at lower moisture levels (Figure 7).

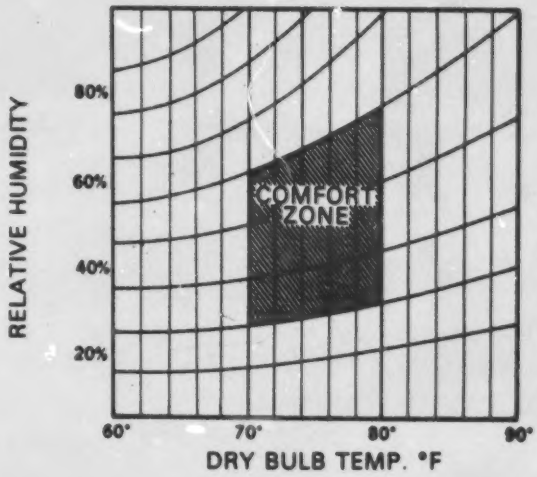

FIGURE 7. Comfort zone.

EVALUATION I-3-1

1. Match terms to definitions:

a. Btu.
b. Btu/hr.
c. Heat flow by conduction.
d. Heat flow by infiltration.
e. Heat flow by radiation.

1. __Rate of heat flow.
2. __Heat flow by solar energy.
3. __Unit of heat.
4. __Heat flow through solids.
5. __Heat loss through air exchange.

2. Match terms to definitions:

a. Thermal conductivity (k-value).
b. Thermal conductance (C-value).
c. Coefficient of heat transfer (U-value).
d. Thermal resistance (R-value).

1. __Heat transferred through a material 1 sq. ft., any thickness.
2. __Heat transferred through a material 1 sq. ft., 1 ft. thick.
3. __Resistance to heat flow.
4. __Heat transferred through a wall section.

3. Match terms to definitions:

a. Infiltration.
b. Ventilation.
c. Fenestration.
d. Kilowatt-hour.
e. Inside design temperature.
f. Outside design temperature.
g. Heating degree day.
h. Cooling degree day.
i. Discomfort index.
j. Relative humidity.
k. Comfort zone.

1. __Introduction of outside air
2. __$0.55\ T_d + 0.2\ T_{dp} + 17.5$
3. __Amount of moisture in the air as compared to its capacity.
4. __Average extreme temperature in a locality.
5. __Average outside degree below 65°F.
6. __3,413 Btu.
7. __Between 72°F and 80°F and 20% and 60% RH.
8. __Windows.
9. __Average outside degree above 75°F.
10. __Winter, 72°F; Summer, 78°F.
11. __Movement of air in and out of a building.

UNIT I

EVALUATION I-3-1
ANSWER KEY

1-1.	B
2.	E
3.	A
4.	E
5.	D
2-1.	B
2.	A
3.	D
4.	C
3-1.	B
2.	I
3.	J
4.	F
5.	G
6.	D
7.	K
8.	C
9.	H
10.	E
11.	A

UNIT I

PLAN SELECTION

COMPETENCY 4 Calculate Heat Loss

LEARNING STEPS

1. Define U-Factor
2. Calculate Heat Loss areas
3. Locate U-Factor

LEARNING ACTIVITIES

1. Attend teacher presentation on heat loss.
2. Read Information Sheet "Terms Used to Measure Energy in Buildings" I-3-1.
3. Refer to Unit I, Competency 1, Learning Activities 3 and 4.
4. Read Information Sheet "Estimating Heating Loads in Buildings", I-3-3.
5. Read Information Sheet "Understanding Heat Losses and Gains in Buildings" I-3-2.
6. Calculate exterior wall areas.
7. Calculate window areas.
8. Calculate door areas.
9. Subtract total of window and door area from exterior wall areas.
10. Calculate exposed ceiling area.
11. Calculate exposed floor area
12. Determine termperature differences from coldest day in your area to 70F.
13. Locate U-Factor for each structural component from American Society of Heating, Refrigeration and Air Conditioning Engineer's Manual or consult local supplier.

Estimating Heating Loads in Buildings

On completion of this section you will be able to estimate the heating load for a building by using the tables at the end of this section and calculating the heat flow in Btu/hr. General procedures are as follows:

1. Find the thermal resistance (R) and the overall transmission coefficient (U=1/R) for the walls, ceilings, roof, windows and floors from working drawings and/or tables. Excerpts are given in Tables V and IX.
2. Calculate the surface areas of the walls, ceiling, floor, windows and doors in each room of the building.
3. Find the design temperatures for the outside air and ground. Excerpts are given in Table II.
4. Establish the desired inside air temperature. Generally 68°F, winter, and 78°F, summer.
5. Calculate the heat loss by conduction through each component of each room using $q_c = UA\ (\Delta t)$.
6. Calculate the conduction loss from each room by adding losses through each component.
7. Calculate the total conduction heat loss from the building by adding the conduction losses from each room.
8. Estimate the infiltration heat loss from each room using $q_i = 0.018\ Q_i\ (\Delta t)$.
9. Calculate the total infiltration loss by adding the infiltration losses from each room.
10. Calculate the heat loss from the entire building by adding the total heat losses due to conduction and infiltration (or ventilation).
11. Estimate the seasonal heating load. Follow procedures under Section 7.

EXAMPLE NO. 6 CALCULATING HEATING LOAD

The building used in this example has been kept very simple in order to emphasize procedural details rather than construction details (Figure 11).

Data and calculations are recorded in Worksheet 1 to help you understand how to do a Worksheet of your own from a new or existing building.

Estimate the heating load for the building plan shown in Figure 11. It is described as follows (see Worksheet 1):

- The house is to be located near Philadelphia, Pennsylvania.
- The design indoor temperature is 65°F in all rooms.
- The house rests on a 4-inch concrete slab on grade with 1-inch thick perimeter insulation (k = 0.24) around the entire slab.
- The exterior walls are of 2" x 4" frame construction with studs 16 inches o.c. The space between studs is filled with 3 1/2 inches of insulation with an R-value of 11. The inside of the wall is covered with 1/2-inch gypsum wallboard, while the outside is sheathed with 1/2-inch asphalt impregnated wallboard and 1/2 x 8-inch wood siding.

- The interior walls are uninsulated and have 1/2-inch gypsum wallboard on each surface.
- The ceiling construction consists of 1/2-inch gypsum wallboard, and 2" x 8" ceiling joists (16" o.c.). The space between the joists are filled with 6 inches of R-19 blanket insulation.
- The roof has a slope of 1:3 and is constructed of 2" x 4" rafters, 16 inches o.c. and covered with 5/8-inch plywood sheathing, felt building paper, and asphalt shingles.
- The windows are all 36 x 60 inches in size and are doubly insulated glass, 0.125 inches thick with 0.25-in air spaces.
- All doors are of 1.5-inch thick wood construction without storm doors. The dimension of each door is 36 x 80 inches.
- The ceiling height is 8 feet.
- All doors and windows are weatherstripped.

SOLUTION:

Follow steps given under the following headings and observe the recorded values in Worksheet 1.

1. Determining Thermal Resistance (R-Values) and Overall Transmission Coefficients (U-Values).
2. Determining Areas of Building Components.
3. Determining Design Temperatures.
4. Calculating Heat Flow by Conduction.
5. Calculating Heat Flow by Infiltration.
6. Calculating Total Heat Flow.
7. Estimating Seasonal Heating Load.
8. Comparing Energy-Saving Practices.

1. DETERMINING THERMAL RESISTANCE (R-VALUES) AND OVERALL TRANSMISSION COEFFICIENTS (U-VALUES)

These values are discussed under the following headings and recorded in Worksheet 1:

a. Walls.

b. Ceilings.

c. Floors.

d. Windows.

e. Doors.

a. Walls

Proceed as follows:

1. Find U-Value from Table V.

   U-Value (Avg.) = .081
   Note recorded in Worksheet 1.

2. Compute R-Value.

$$\text{R-Value} = \frac{1}{.081} = 12.35$$

b. Ceilings

Proceed as follows:

1. Find U-Value for roof from Table IX. The ceiling and roof act in combination in determining the heat loss through the roof area. Table IX gives the U- and R-Values for a pitched roof (with a 45° slope) with reflective and non-reflective air spaces. This example building has a slope of 1:3 (approximately 20°), a non-reflective air space between the roof and ceiling and 6 inches of insulation (R-19).

For the roof with non-reflective air space and no insulation, U-0.273 (From Table IX, for winter conditions with heat flow up).

2. Find ceiling-roof combination with insulation (R-19) from Table X.

(1) Enter Table X with a U-Value of 0.273 or approximately 0.30 in the first column.

(2) Proceed to the right to the column most nearly corresponding to the installed R-Value of insulation (R=20).

(3) Read directly the overall transmission coefficient of the roof-ceiling combination.

U = 0.04. Thus, R = 1/.04 = 25.

Note U-Value recorded in Worksheet 1. By using the roof-ceiling combination for the R-Values, the design outside and inside temperatures can be used in future heat loss calculations. It is not necessary to evaluate the attic space temperature. If the attic is well ventilated, use the R-Value for the ceiling construction and outside design air temperature.

c. Floors

The R-Value of the floor in this problem is not required since Table XI allows direct estimation of the floor slab heat losses in Btu/hr as a function of linear feet of exposed slab edge and outdoor design temperatures (See Figure 11).

It is given in Btu/hr per linear foot of exposed edge.

Proceed as follows:

1. Assume outside design temperature of -10 to -20 F.

2. Find heat loss in column 2 for 1" edge insulation (Table XI).

50 Btu/(hr-Ft)

d. Windows

Proceed as follows:

1. Find U-Value for double insulated .25 inch air space in Table XII. Double insulated, no indoor shade, winter:
U-Value = 0.58.
Note recordings in Worksheet 1.

2. Compute R-Value.

$$\text{R-Value} = \frac{1}{0.58} = 1.72.$$

e. Doors

Proceed as follows:

1. Find U-Value for 1.5-inch doors without storm doors in Table XIII.

U-Value = 0.49
Note recordings in Worksheet 1.

2. Compute R-Value.

$$\text{R-Value} = \frac{1}{0.49} = 2.04$$

2. DETERMINING AREAS OF BUILDING COMPONENTS

Assume that all the rooms are to be kept at the same temperature. Then there will be no heat transferred through interior walls, and it is necessary only to calculate the area of the exterior walls. To illustrate, find the required areas for room 3 in Figure 11 as follows (See Worksheet 1):

1. Compute exterior wall area (Room 3).

25' x 8' - 3' x 6.67' = 180 ft.^{2}

25' x 8' - 3'x5' - 3'x5' = 170 ft.^{2}

20' x 8' - 3' x 5' = 145 ft.^{2}

Total 495 ft.^{2}

2. Compute ceiling area (Room 3).

20' x 25' = 500 ft.^{2}

3. Compute window area (Room 3).

3(3' x 5') = 45 ft.^{2}

4. Compute door area (Room 3).

3' x 6.67 = 20 ft.^{2}

5. Compute exposed slab length (Room 3).

25' + 20' + 25' = 70 ft.

6. Calculate areas for other rooms in the same manner.

3. DETERMINING DESIGN TEMPERATURES

1. Select inside design temperature (t_i). For this example use 65°F. Many designers use 68°F.

2. Select outside design temperature (t_o). Outside design temperatures for Philadelphia, PA are given in Table II. Two winter design conditions are given; one under the 99% column and one under the 97.5% column. These percentages are the percentage of the total number of hours during the months of December, January and February that the listed temperature is exceeded in an average year. For a residential building, the 97.5% design temperature is usually adequate.

Thus, the outside design temperature, t_o, is 14°F and $t_i - t_o = 65-14 = 51$°F.

4. CALCULATING HEAT FLOW BY CONDUCTION (q_c)

Proceed as follows (see Worksheet 1): (Calculations are shown for room #3 only.)

1. Find heat flow through walls (Room 3).

q_c (walls) = U (wall) A (wall) (t_i-t_o)

$q_c = .081 \times 495 \times 51 = 2045$ Btu/hr

2. Find heat flow through ceiling (Room 3).

q_c (ceilings) = U (ceiling-roof) A (ceiling) (t_i-t_o)

$q_c = .04 \times 500 \times 51 = 1020$ Btu/hr

3. Find heat flow through floor (Room 3).

q_c (floor) = factor from Table XI x exposed length of slab

$q_c = 50 \times 70 = 3500$ Btu/hr

4. Find heat flow through windows (Room 3).

q_c (windows) = U (windows) A (windows) $(t_i - t_o)$

$q_c = 0.58 \times 45 \times 51 = 1330$ Btu/hr

5. Find heat flow through doors (Room 3).

q_c (doors) = U (Doors) A (Doors) $(t_i - t_o)$

$q_c = 0.49 \times 20 \times 51 = 500$ Btu/hr

6. Find total heat flow through each room.
From steps 1, 2, 3, 4 and 5:

For room 3, 2045 + 1020 + 3500 + 1330 + 500 = 8395 Btu/hr.

NOTE: The values for rooms 1 and 2 are obtained in the same manner as those for room 3. The values are summarized and listed in Worksheet 1.

7. Find total heat flow by conduction from building.

Add heat flow for each room.

q_c (room 1) = 4959
q_c (room 2) = 3936
q_c (room 3) = 8395

Total q_c = 17,290 Btu/hr

5. CALCULATING HEAT FLOW BY INFILTRATION

Calculate the infiltration heat losses from each room as follows (see Worksheet 1):

1. Find air exchanges (Q_i) from Table VI. Use 2/3 since windows have storm sashes (Table VI).

Q_i (Room 1) = 2/3 (1.5) (15 x 15 x 8) = 1800 ft^3/hr
Q_i (Room 2) = 2/3 (1.0) (15 x 20 x 8) = 1600 ft^3/hr
Q_i (Room 3) = 2/3 (2.0) (20 x 25 x 8) = 5360 ft^3/hr

2. Find heat flow by infiltration for each room (q_i).

$q_i = .018 Q_i (\Delta t)$
q_i (Room 1) = .018 (1800) (51) = 1652 Btu/hr
q_i (Room 2) = .018 (1600) (51) = 1468 Btu/hr
q_i (Room 3) = .018 (5360) (51) = 4290 Btu/hr

3. Find total heat flow by infiltration (q_i).

Add heat flow from each room:
1652 + 1468 + 4920 = 8040 Btu/hr

6. CALCULATING TOTAL HEAT FLOW

Add heat flow by conduction and heat flow by infiltration.

q_c = 17,290
q_i = 8,040

q = 25,330 Btu/hr

NOTE: A blank Worksheet 2 is provided for you to calculate heat flow from your own new or existing building (in the student workbook).

WORKSHEET 1. HEAT FLOW CALCULATIONS

Overall Heat Transfer Coefficients (U)
Exterior Walls 0.081 Btu/hr-ft^2-°F
Ceiling-Roof Comb 0.04 Btu/hr-ft^2-°F
Floors N/A Btu/hr-ft^2-°F
Slabs 50 Btu/hr-ft
Windows 0.58 Btu/hr-ft^2-°F
Doors 0.49 Btu/hr-ft^2-°F

Design Temperatures
Inside Temperature (t_i) 65°F
Outside Temperature (t_o) 14°F

Room	Building Component	Transmission Coefficient (U)	Surface Area (A)	Temp. Difference ($t_i - t_o$)	Conduction Losses $q_c = UA(\ t)$	Air Exchange	Infiltration Rate (Q_i)	Infiltration Losses $q_i = .018Q_i(\ t)$
	Ext. walls	.081	330	51	1363			
	Ceiling-roof	.04	225	51	459			
	Floor	-	-	-	-			
1	Slab	50*	45*	-	2250*			
	Windows	.58	30	51	887			
	Doors	.49	0	51	0			
	TOTAL ROOM LOSS				4959	1.5	1800	1652
	Ext. walls	.081	260	51	1074			
	Ceiling-roof	.04	300	51	612			
	Floor	-	-	-	-			
2	Slab	50*	35*	-	1750*			
	Windows	.58	0	51	0			
	Doors	.49	20	51	500			
	TOTAL ROOM LOSS				3936	1.0	1600	1468
	Ext. walls	.081	495	51	2045			
	Ceiling-roof	.04	500	51	1020			
	Floor	-	-	-	-			
3	Slab	50*	70*	-	3500*			
	Windows	.58	45	51	1330			
	Doors	.49	20	51	500			
	TOTAL ROOM LOSS				8395	2.0	5360	4920

*Slab Loss - Factor from Table XI x Exposed Perimeter Length.

Total Conduction Loss = 4959 + 3936 + 8395 = 17,290 Btu/hr.
Total Infiltration Loss = 1652 + 1468 + 4920 = 8,040 Btu/hr.
Total Heat Loss = 17,290 + 8,040 = 25,330 Btu/hr.

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7. ESTIMATING SEASONAL HEAT LOAD

The procedures described and illustrated thus far allow computation of the heat loss from a building when the outdoor temperatures are at the design, or some other specific, temperature. This occurs for only a few hours, or instants, during the heating season. The seasonal heating load can be estimated by evaluating heat losses on an hour by hour basis. However, this procedure would be too time consuming. Instead, an approximate method known as the Degree-Day Method has been recommended by ASHRAE for predicting seasonal heat losses and fuel consumption.

The Degree Day Method estimates seasonal heating loads by assuming there is no heat loss or gain when the outdoor temperature is 65°F and then predicting from weather data the number of hours in the heating season for which the outdoor temperature is below 65°F. The total number of hours for which the outdoor temperature is less than 65°F is called the number of Degree Days for the building location. The number of degree days is dependent upon climate. Typical values are summarized for several locations in Table II.

The seasonal heat loss is estimated by the equation:

$$q_s = \frac{q \times D \times 24}{\Delta t}$$

where q_s = seasonal heat loss, Btu
q = heat loss at design temperatures, Btu/hr
D = number of degree days, F. days
Δt = design temperature difference, °F
24 = 24 hour day

To estimate the fuel consumption during a heating season, the heating value of the fuel and several efficiency factors must be applied to the seasonal heat loss value, q_s.

$$E = q_s \frac{C_D \times C_F}{\gamma \times v}$$

where E = seasonal fuel or energy consumption
C_D = correction factor heat loss differences
C_F = correction factor for partial loads for fuel-fired systems. (Use 1.0 for electric resistance heating.)
γ = rated full load efficiency of heating equipment (decimal value).
v = heating value of fuel in units consistent with E and q_s. (Btu/gal, Btu/cu. ft, Btu/kwh)

Suggested values of C_D and C_F are found in Tables XIV and XV. Full load efficiencies are usually between 70% and 80% and are available from manufacturers.

EXAMPLE NO. 7. SEASONAL HEAT LOAD ESTIMATION.

Consider the same situation described in Example Problem No. 1. Assume the heating system has a capacity of 30,000 Btu/hr.

Step 1: Evaluate the seasonal heat loss.

$$q_s = \frac{q \times D \times 24}{t}$$

q = 25,330 Btu/hr (From Example Problem No. 6, Worksheet 1)
D = 5144 degree days (Table II)
Δt = 65°-14° = 51°F

Thus $q_s = \frac{25,330 \times 5,144 \times 24}{51}$

$= 61,300,000$ Btu/season.

Step 2: Evaluate the quantity of fuel required per heating season.

$$E = q_s \frac{C_D \times C_F}{\gamma \times v}$$

$C_D = 0.83$ (Table XIV at 14°F design temperature).

$C_F = 1.56$ (Table XV for 25% oversized heating unit.)

γ = Efficiency .75, fuel oil; 1.00 electricity.

$v = 800$ Btu/ft^3 gas.

$v = 144,000$ Btu/gal fuel oil

$v = 3,413$ Btu/kwh electrical energy.

Thus the estimated quantity of fuel consumed is

$E = 61,300,000 \left(\frac{0.83 \times 1.56}{0.75 \times 800}\right) =$ 132,000 cu. ft. gas.

$E = 61,300,000 \left(\frac{0.83 \times 1.56}{0.75 \times 144,000}\right) =$ 735 gal. fuel oil

$E = 61,300,000 \left(\frac{0.83 \times 1.56}{1.0 \times 3413}\right) =$ 23,250 KWh electrical energy.

8. COMPARING ENERGY-SAVING PRACTICES

It is often desirable to compare the energy savings realized by an energy-saving practice. This section outlines and illustrates the procedures for comparing the effect of various practices.

The house in Example No. 6 will be used to compare the energy consumption for the house specifications as given and for the same house without any insulation or weatherstripping. All the calculations will not be shown for the uninsulated house. Instead, the entries in Worksheet 1 which are affected by the modification in specs will be crossed out and replaced in longhand with the correct values.

Basically two items must be corrected for the modified house specifications; namely, the transmission coefficients for the walls, ceilings, and slab and the air exchange rates. These corrections along with their consequences are summarized in Worksheet 2.

EXAMPLE NO. 8: COMPARING ENERGY-SAVING PRACTICES

1. Evaluate the design heat loss for the modified specification (no insulation or weatherstripping).

(1) Change exterior wall transmission coefficient to 0.206 (Table V).

(2) Change ceiling-roof transmission coefficient to 0.273 (Table IX).

(3) Change slab transmission factor to 60 (Table XI).

(4) Calculate new conduction loss column entries.

(5) Calculate new total conduction loss entry.

(6) Change infiltration rate to full value as given in Table VII.

(7) Calculate new infiltration loss entries.

(8) Calculate new total infiltration loss entry.

(9) Evaluate total heat loss.

2. Evaluate the change in the seasonal heat loss, q_s.

(1) For the insulated, weather-stripped building, q_s= 61,300,000 Btu/season.

(2) For the uninsulated, non-stripped building,

$$q_s = \frac{49,925}{25,330} \times 61,300,000 =$$

122 million Btu/season.

(3) The increase in heat loss is 122-61.3, or 60.7 million Btu/season.

This represents an increase of $\frac{60.7}{61.3} = 99\%$.

3. Evaluate the change in the quantity of fuel required per season.

Use fuel oil for the illustration.

(1) For the insulated, weather-stripped building.

E = 735 gallons fuel oil/season.

(2) For the insulated building,

$$E = 122,000,000 \left(\frac{0.83 \times 1.56}{0.75 \times 144,000}\right)$$

= 1535 gallons fuel oil/season

(3) Find the increase in fuel oil consumption.

1535 - 735 or 800 gallons.

The annual cost of fuel for heating for the current season can be evaluated by multiplying the seasonal fuel consumption, E, by the unit cost of the fuel. Similarly, the current year savings in fuel cost is simply the change in fuel consumption times the unit fuel cost. In the illustration just completed, if the cost of fuel oil is $0.50 gallon, the addition of insulation and weatherstripping would reduce the annual cost for heating fuel by 0.50 (800), or $400. Of course, as fuel costs increase, the dollar savings will also increase.

WORKSHEET 2. HEAT FLOW CALCULATIONS

Overall Heat Transfer Coefficients (U)

Exterior Walls ~~0.081~~ Btu/hr-ft²-°F .206
Ceiling-Roof Comb ~~0.04~~ Btu/hr-ft²-°F .273
Floors N/A Btu/hr-ft²-°F
Slabs ~~.50~~ Btu/hr-ft 60
Windows 0.58 Btu/hr-ft²-°F
Doors 0.49 Btu/hr-ft²-°F

Design Temperatures

Inside Temperature (t_i) 65°F

Outside Temperature (t_o) 14°F

Room	Building Component	Transmission Coefficient (U)	Surface Area (A)	Temp. Difference ($t_i - t_o$)	Conduction Losses $q_c = UA(\Delta t)$	Air Exchange	Infiltration Rate (Q_i)	Infiltration Losses $q_i = .018 Q_i(\Delta t)$
1	Ext. walls	~~.081~~ .206	330	51	~~1363~~ 3467			
	Ceiling-roof	~~.04~~ .273	225	51	~~459~~ 3133			
	Floor	-	-	-	-			
	Slab	~~.50~~ .60	45*	-	~~2250~~* 2700			
	Windows	.58	30	51	887			
	Doors	.49	0	51	0			
	TOTAL ROOM LOSS				~~4959~~ 19,187	1.5	~~1800~~ 4700	~~1652~~ 2478
2	Ext. walls	~~.081~~ .206	260	51	~~1074~~ 2731			
	Ceiling-roof	~~.04~~ .273	300	51	~~612~~ 4179			
	Floor	-	-	-	-			
	Slab	~~.50~~ .60	35*	-	~~1750~~* 2100			
	Windows	.58	0	51	0			
	Doors	.49	20	51	500			
	TOTAL ROOM LOSS				~~3936~~ 9,508	1.0	~~1600~~ 2400	~~1468~~ 2203
3	Ext. walls	~~.081~~ .206	495	51	~~2045~~ 5200			
	Ceiling-roof	~~.04~~ .273	500	51	~~1020~~ 6962			
	Floor	-	-	-	-			
	Slab	~~.50~~ .60	70*	-	~~3500~~* 4200			
	Windows	.58	45	51	1330			
	Doors	.49	20	51	500			
	TOTAL ROOM LOSS				~~8395~~ 18,192	2.0	~~5360~~ 8000	~~4920~~ 7344

*Slab Loss - Factor from Table XI x Exposed Perimeter Length.

Total Conduction Loss = ~~4959~~ + ~~3936~~ + ~~8395~~ = ~~17,290~~ Btu/hr. 19,187 + 9,508 + 18,192 = 37,887 Btu/hr.
Total Infiltration Loss = 1652 + ~~1468~~ + ~~4920~~ = ~~8,040~~ Btu/hr. 2478 + 2203 + 7344 = 12,025 Btu/hr.
Total Heat Loss = ~~17,290~~ + ~~8,040~~ = ~~25,330~~ Btu/hr. 37,887 + 12,025 = 49,912 Btu/hr.

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UNIT I

PLAN SELECTION

COMPETENCY 5: Calculate heat gain for cooling

LEARNING STEPS:

1. Define or review terms
2. Determine hottest degree Fahrenheit temperature for area
3. Determine desired temperature for comfort
4. Calculate heat gain for cooling using heat transfer formula

   Heat Gain = Surface area x change in temperature x U-Factor for structural component

LEARNING ACTIVITIES:

1. Attend instructor's lecture on calculating heat gain for cooling.
2. Refer to Information Sheet I-3-1 "Terms Used to Measure Energy in Buildings.
3. Read Information Sheets II-4-1 and II-4-2 Calculate area for structural components (doors, windows, exposed wall, ceiling and floor area)
4. Locate U-Factor for components
5. Calculate heat gain for structural components
6. Determine total heat gain

EVALUATION: Given a floor plan and the U-Factor for each structural component calculate the heat gain of a structure

Special Applications for Estimating Cooling Loads in Buildings

Cooling loads in buildings differ from instantaneous heat gain calculations because of flywheel effects. That is, some of the heat gained during the hottest portion of the day is stored in the building furnishings, walls and partitions and need not be removed until sometime later when the outdoor temperatures are lower and the instantaneous heat gain is smaller. Numerous techniques have been devised to account for this flywheel affect when calculating residential cooling loads.

Cooling loads are estimated by evaluating sensible cooling loads due to: (1) heat gain through floors, walls, ceilings; (2) windows; (3) infiltration and ventilation air exchange; and (4) occupancy. Then the latent cooling load (that required to control and remove excess moisture) is evaluated. A rule of thumb is to assume the latent cooling load is 0.3 times the sensible cooling load.

To help you understand the difference between heating loads and cooling loads, discussion is given under the following headings:

1. Cooling Load Due to Heat Gain Through Walls, Floors, Roofs and Ceilings.
2. Cooling Load Due to Windows.
3. Cooling Load Due to Infiltration.
4. Cooling Load Due to Occupancy.
5. Latent Cooling Load.
6. Total Cooling Load.

1. COOLING LOAD DUE TO HEAT GAIN THROUGH WALLS, FLOORS, ROOFS AND CEILINGS

The cooling load due to heat gain through structural components may be calculated by using an equivalent difference between the inside and outside temperatures in place of the actual indoor-outdoor temperature differences. Typical values of Equivalent Temperature Differences (ETD) are given in Table XVI. The ETD takes into account such factors as sol-air temperatures, construction type, thermal flywheel effects, and daily temperature ranges, and outdoor design temperatures. The cooling load due to structural components is obtained using equation (13):

$$q_{cs} = UA(ETD) \quad \text{. . . Equation (13)}$$

To enter the table of ETD's, one must obtain both the outdoor design temperature and the range of daily temperatures for the building site (Table II). ETD's are given in 5°F increments of design temperatures from 85°F to 110°F (Table XVI). Daily temperature ranges are given for 3 conditions: I(0-15°F), M(15-25°F), and H(over 25°F). ETD's for design temperatures not listed can be obtained by adding 1°F to the tabulated value for each degree increase in design temperature. For this problem, walls are all assumed to be dark walls in Table XVI. Roofs, on the other hand, may be either dark or light colored.

2. COOLING LOAD DUE TO WINDOWS

The equivalent temperature difference concept has also been adopted to simplify cooling loads due to heat gains through window areas. Typical values of equivalent temperature differences (ETD) are given in Table XVII. The ETD's are given for 4 types of glass (regular, single glass, regular double glass, heat absorbing double glass, and clear triple glass, 6 design temperatures (85 to 110°F), for 8 compass points (N, S, E, W, etc.), and for 4 window treatments (no drapes, draperies, roller shades, and awnings). The ETD's are based upon an indoor temperature of 75°F.

The cooling load for windows is then calculated using equation 13, as was done for walls.

Permanent shades, such as overhangs, will reduce the cooling load due to windows. Shaded windows are considered as North-facing windows to get ETD's. Most permanent shades will shade only a portion of the window area. Thus, it is necessary to determine the extent of shading, or the shade line, for each window. Table XXIII gives typical shade line factors for several latitudes and window orientation. The shade line will extend downward over the shaded wall for a distance equal to the shade line factor (from Table XVIII) times the overhang width. The shaded portion of the window is then assumed to be a North-facing window for its ETD while the orientation of the remaining portion of the window is not altered for its ETD. Note that NE and NW facing windows are not effectively protected by permanent shades.

3. COOLING LOAD DUE TO INFILTRATION

Infiltration and ventilation air exchanges are smaller in warm weather than in cold weather. The infiltration and ventilation cooling loads given in Table XIX reflect this difference. Infiltration cooling loads are obtained by multiplying the area of the exposed wall area times the factor given in Table XIX for a specific design temperature. Ventilation cooling load is calculated by multiplying the factor in Table XIX times the cfm capacity of the ventilation fans. Most residences do not have mechanical ventilation systems and rely upon infiltration for their ventilation.

4. COOLING LOAD DUE TO OCCUPANCY

The cooling load due to occupants and appliances is usually approximated. The load per occupant is approximately 225 Btu/hr and the number of occupants may be estimated at twice the number of bedrooms unless a lot of large group entertaining is anticipated.

The cooling load due to appliances in most residences can be limited to the kitchen and estimated at 1200 Btu/hr.

5. LATENT COOLING LOAD

The latent cooling load may be estimated at 20 to 30% of the sensible cooling load.

6. TOTAL COOLING LOAD

The total cooling load is the sum of the sensible cooling load through the structural components, windows, infiltration gains, occupancy gains, and moisture removal (latent cooling load).

Estimating Cooling Loads in Buildings

The cooling load for a building can be estimated by using the tables and calculating the heat gained in Btu/hr. From this section you will be able to calculate the cooling loads in buildings. General procedures are as follows:

1. Estimate the overall heat transmission coefficient, (U), for walls, ceilings, roof, windows, doors and floors.

   Refer to Tables II, III, IX, X, XI, XII, and XIII.

2. Figure the surface areas of the walls, ceilings, floor, windows, doors and floors on each room.

3. Find the design indoor and outdoor temperatures.

   Refer to Table III.

4. Determine the equivalent temperature differences, ETD, for each component in each room.

   Refer to Table XVI.

5. Evaluate the conduction sensible cooling load required for each component.

   Use equation 13, $Q_{cs} = UA\ (ETD)$

6. Evaluate the conduction sensible cooling load for each room.

   Add cooling load for each component.

7. Evaluate the infiltration sensible cooling load in each room by using factors in Table XIX and the gross exterior wall area and mechanical ventilation rates.

8. Evaluate the total sensible cooling load for each room by adding the conduction sensible cooling load and the infiltration sensible cooling loads.

9. Evaluate the total cooling load for each room by increasing the sensible cooling load per room by a factor of 1.3.

   This increase accounts for the cooling load required to remove moisture from the residence.

10. Evaluate the total cooling load by adding the cooling loads for each room.

Determining Cost Benefits of Using Energy-Saving Practices

The bottom line of any energy conserving practice is the relative benefit to cost ratio or the time required to recoup the investment. In other words, the planner or homeowner needs to evaluate whether the energy savings (in dollars) is enough to offset the additional cost of additional insulation. In addition, you may not wish to sacrifice comfort, looks and lifestyle for some practices.

A benefit/cost analysis allows us to make a direct comparison between the present value of the energy savings (in dollars) over the expected life of the energy-saving practice to the first cost and maintenance of the energy-saving practice. If the benefit/cost ratio exceeds one, the energy-saving practice is economically feasible, whereas if the ratio is less than one, the practice will not pay for itself.

The benefit/cost ratio is evaluated by the formula:

$$\text{Benefit/Cost Ratio} = \frac{\text{Present Value of Net Annual Savings}}{\text{First Cost of the Energy-Saving Practice and Maintenance (if any)}}$$

The present value of the net annual savings is calculated by:

$$\text{Present Value} = \text{Net Annual Savings} \times \text{Present Worth Factor}$$

From your study of this section, you will be able to calculate cost benefits and payback periods for energy-saving practices.

Follow procedures under the following headings:

1. Calculating the Benefit/Cost Ratio.
2. How Expected Life Affects the Benefit/Cost Ratio.
3. How Increase in Fuel Prices Affects the Benefit/Cost Ratio.
4. How Interest Rates Affect the Benefit/Cost Ratio.
5. Calculating the Payback Period.

Unit I
PLAN SELECTION

COMPETENCY 6: Determine yearly heating and cooling costs of structure

LEARNING STEPS:

1. Calculate total heat loss of structure
2. Calculate total heat gain of structure
3. List cost per BTU for gas, electric, coal, wood and oil heating and cooling systems
4. Obtain yearly energy use estimates from local energy suppliers

LEARNING ACTIVITIES:

1. Obtain cost and BTU output per unit for energy in area
2. Prepare a chart showing BTU's of energy per unit of energy and cost per BTU

   Unit BTU/unit Cost/unit Cost/BTU
3. Calculate heat loss for structure
4. Calculate heat gain for structure
5. Obtain yearly energy consumption estimate from local suppliers

   Refer to Information Sheets I-3-2; I-3-3 and II-4-1

EVALUATION: Given a house plan estimate total heating cost and cooling cost for one year

Understanding Heat Losses and Gains in Buildings

Heat transfer through building sections is computed by the use of formulas. Once you understand the formulas, it is a simple matter to substitute the values and arrive at heat losses or gains.

From your study of this section you will be able to explain which formulas are used for determining heat transfer in buildings and the terms used.

They are discussed under the following headings:

1. Conduction Heat Flow Through Homogeneous Materials.
2. Conduction Heat Flow Through Composite Walls.
3. Infiltration Heat Losses or Gains.
4. Ventilation Heat Losses or Gains.
5. Radiation Heat Losses or Gains.
6. Energy Losses and Gains from Equipment Operation.

1. CONDUCTION HEAT FLOW THROUGH HOMOGENEOUS MATERIALS

The fundamental relationship defining conduction heat flow through a homogeneous solid is the Fourier equation:

$$\text{Heat Transfer (Btu/hr)} = \frac{\text{Conductivity of material (k) x surface area (sq. in.)}}{\text{Thickness in inches}} \times \text{Temperature Difference between the sides of the solids } (t_2 - t_1) \text{ in °F}$$

or

$$q_c = \frac{kA}{L}(t_2 - t_1)$$

Where

q_c = Heat flow by conduction (Btu/hour).
k = Thermal conductivity of the material, Btu/hr x ft^2 x °F x In.
L = Thickness of the solid in the direction of heat flow in inches.
$(t_2 - t_1) = \Delta T$ = Temperature difference between the two surfaces of the solid (°F).
A = Area of the solid perpendicular to the direction of heat flow.

The terms in equation 1 are illustrated in Figure 8.

It is important that equation 1 and its implications be understood. Notice that the heat transfer by conduction through the material will be small if:

- A material with a small conductivity (k) is used.
- The material thickness (L) is large.
- The temperature difference $(t_2 - t_1)$ between the two surfaces is kept small.
- The area (A) of the wall is kept small.

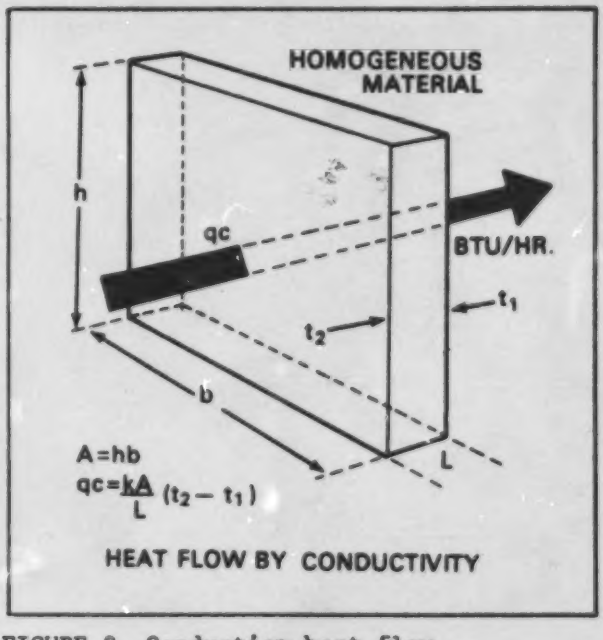

FIGURE 8. Conduction heat flow definition sketch.

Conduction heat losses in a building can be minimized by decreasing the building size, by selecting thick materials with low thermal conductivities, and by reducing the temperature difference between inside and outside air.

The thermal conductivity (k) of a material is a physical property which is obtained experimentally in the laboratory. Note that the conductivity is based on a material thickness of unity, or 1 inch. The conductivities of selected building materials are given in Table III.

Often, the thermal conductivity (C) of a material is given for a specified thickness rather than for a unit thickness. Typical cases are 8-inch concrete masonry blocks, or dressed timber boards. When the thermal conductivity is given for a specified thickness, it is called the thermal conductance (C). Typical values of thermal conductance are also given in Table IV.

When thermal conductances of materials are used, the conduction heat transfer equation must be modified since the material thickness is already incorporated into the conductance value. Thus

$$\underset{\text{(Btu/hr)}}{\text{Heat Transfer}} = \underset{\text{(C)}}{\text{Thermal Conductance}} \times \underset{\text{(A)}}{\text{Area}} \times \underset{(t_2 - t_1)}{\text{Temperature Difference}}$$

$$q_c = CA\,(t_2 - t_1) \quad \text{. . . . (Equation 2)}$$

where C = thermal conductance, Btu/hr x ft^2 x $\Delta t°F$.

Another common way to describe a material's ability to conduct heat is its thermal resistivity (r) and thermal resistance (R). The resistivity is the reciprocal of the conductivity, whereas, the resistance is the reciprocal of the conductance. That is, the resistivity is the material's resistance to heat flow per unit thickness and the resistance is the material's resistance to heat flow for a specified thickness. Typical resistances are given for some insulation materials in Table I.

$$\underset{\text{(r)}}{\text{Thermal Resistivity}} = \frac{1}{\text{Conductivity (k)}}$$

$$R = \frac{1}{\text{Conductance (C)}} = \frac{\text{Thickness of material}}{\text{Conductivity (k)}}$$

$r = 1/k$ and $R = 1/C = L/k$ . . (Equation 3)

The conduction heat flow equation for a single material can now be expressed in terms of thermal resistivity and resistance by:

$$\underset{\text{(Btu-hr) } (q_c)}{\text{Conduction Heat Flow}} = \frac{1}{\text{Resistance (R)}} \times \frac{\text{Area (A) } (ft^2)}{\text{Thickness (L) (in)}} \times \underset{(t_2 - t_1)}{\text{Temperature Difference}}$$

$$q_c = \frac{1}{r}\frac{A}{L}(t_2 - t_1), \text{ and . . . (Equation 4)}$$

$$q_c = \frac{1}{R} A\,(t_2 - t_1) \quad \text{. . . . . (Equation 5)}$$

EXAMPLE NO. 1

To illustrate the use of the conduction equation, suppose a 4' x 8' sheet of 1/2-inch thick plywood has surface temperatures of 100°F and 70°F. Evaluate the heat conducted through the panel.

The thermal properties of the plywood are: k = 0.80
C = 1.60
r = 1.25
R = 0.625

The heat conducted in Btu/hour may be calculated by either equation (1), (2), (4) or (5):

$$q_c = \frac{kA}{L}(\Delta t) = \frac{0.8(4x8)\ (100-70)}{0.5} = 1536 \text{ Btu/hr}$$

$$q_c = CA\ (\Delta t) = 1.6(4x8)\ (100-70) = 1536 \text{ Btu/hr}$$

$$q_c = \frac{A}{rL}(\Delta t) = \frac{1}{1.25}\frac{(4x8)}{0.5}(100-70) = 1536 \text{ Btu/hr}$$

$$q_c = \frac{A}{R}(\Delta t) = \frac{4x8}{0.625}(100-70) = 1536 \text{ Btu/hr}$$

2. CONDUCTION HEAT FLOW THROUGH COMPOSITE WALLS

If structural components were made of single homogeneous materials, equations (1), (2), and (4) would be adequate to estimate conduction heat flow. Most wall partitions, however, are composite walls. That is, they are constructed of two or more materials as shown in Figure 9.

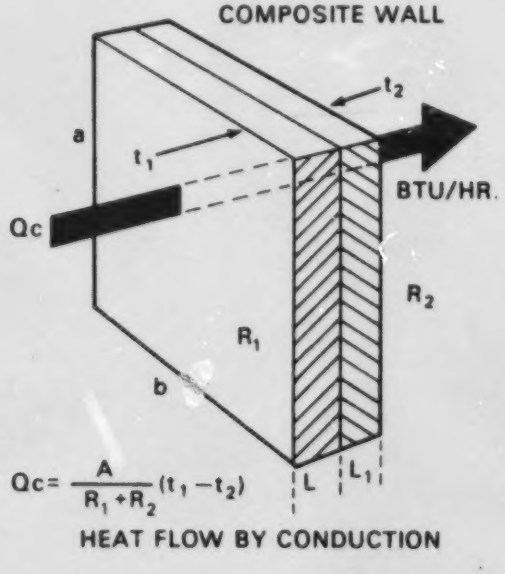

FIGURE 9. Definition sketch for a composite wall.

The procedures for estimating heat flow through a composite wall follow:

The total thermal resistance (R_T) of the composite wall is the sum of the resistance of each component of the wall. In equation form

$$R_T = R_1 + R_2$$

$$R_T = L/k_1 + L/k_2 \quad \ldots \text{ (Equation 6)}$$

By placing the total thermal resistance into the conduction equation, the conduction heat transfer through a composite wall is

$$q_c = \frac{1}{R_T}A\ (\Delta t) \quad \ldots \text{ (Equation 7)}$$

Another way to write equation 7 is to let U = 1/R; then

$$q_c = UA\ (\Delta t) \quad \ldots \text{ (Equation 8)}$$

where U = overall heat transmission coefficient, Btu/hr x ft^2 x °F.

When determining the overall thermal resistance of a wall, it is only necessary to add up the resistances of each component in the wall. Fortunately, the total thermal resistance and overall thermal transmission coefficients are tabulated for many partition constructions.*

*From Table V.

The following example will illustrate how to evaluate overall transfer coefficients and heat flow through composite walls.

EXAMPLE NO. 2

Evaluate the conduction heat transferred through a 8' x 10' wall section composed of 3/4-inch wood siding, 3 1/2-inches fiberglass insulation and 1/2-inch gypsum board (Figure 10).

Outside temperature (t_o) 10°F.
Inside temperature (t_i) 68°F.

	R-Values *
Outside film	0.17
Wood siding	0.81
Sheathing	1.32
Insulation	11.
Gypsum board	0.45
Inside film	.68
R_T =	14.43

*From Table V.

NOTE: There is a small amount of resistance due to the air film on both the outside and inside surface of materials.

$q_c = UA\ (\Delta t)$

$R_T = R_o + R_{sh} + R_{wood} + R_{insul} + R_{gb} + R_i = 0.17 + 1.32 + 0.81 + 11.0 + 0.45 + 0.68 = 14.43$

Thus $U = 1/R_T = 1.14.43 - 0.069$

and $q_c = 0.069\ (8x10)\ (68-10) =$ 321 Btu/hr.

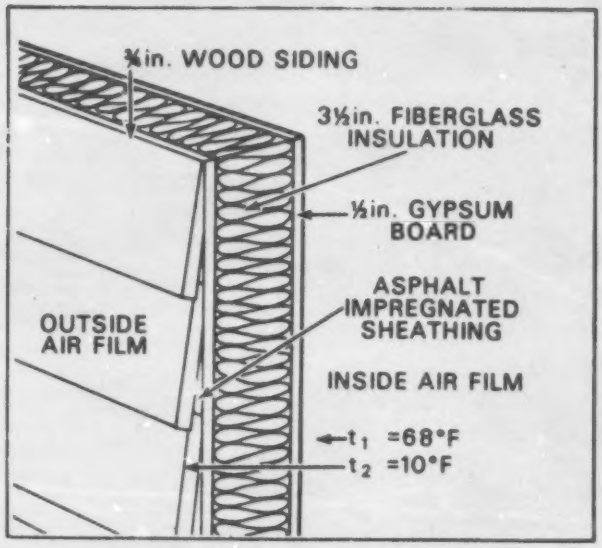

FIGURE 10. Sketch of wall section for conduction heat flow through a composite wall.

Using Table V, the overall heat transfer coefficient is U-0.081. The discrepancy between U calculated (.069) and U tabulated (0.081) is that the tabulated values account for the difference in thermal resistance at the studs and between the studs. The tabulated U-Value is the weighted average of the U-Values at and between the studs.

To illustrate the value of insulation, consider the same composite wall, but remove the 3 1/2 inches of insulation. Now the insulation is replaced by a vertical air space which has a resistance of 1.01 and

$R_T = R_o + R_{sh} + R_{wood} + R_{air} + R_i$

$= 0.17 + 1.32 + 0.81 + 1.01 + 0.45 + 0.68 = 4.44$

and $U = 1/R = 1/4.44 = 0.23$

and $q_c = UA\ (\Delta t) = 0.23\ (8x10)\ (68-10) = 1044$ Btu/hr

Note that by removing the insulation, the heat flow by conduction through the wall increased from 321 to 1044 Btu/hr. The heat loss increased by a factor of 2.25.

EXAMPLE NO. 3

To illustrate the influence of indoor temperature upon heat loss from a building, consider again the insulated wall section with U - 0.069. Compare the heat flow through the wall for an outdoor temperature of 10°F and inside temperatures of both 60°F and 72°F.

At 60°F, $q_c = UA\ (\Delta t) = 0.069\ (80)\ (60-10) = 276$ Btu/hr.

AT 72°F, $q_c = UA\ (\Delta t) = 0.069\ (80)\ (72-10) = 342$ Btu/hr.

By increasing the indoor temperature from 60° to 72°F, Δt increased and thus increased the heat loss through the wall by 66 Btu/hr, or by 24%.

3. INFILTRATION HEAT LOSSES OR GAINS

Outside air enters a residence through many unplanned cracks in walls, doors and windows. This air movement is called infiltration. Since infiltration air is seldom at the temperature of the air inside the living area, it must be warmed or cooled. This fact, of course, represents a heat loss by the house during cold weather and a heat gain by the house during warm weather.

In estimating infiltration heat flow, it is necessary to estimate first the volume, or cubic feet, of air which flows into the building. The quantity of air flow is dependent upon many factors, including the number and sizes of cracks in the structural components and the outside wind speed.

There are two basic methods for evaluating the infiltration air volume. One method requires that the crack widths and lengths and the wind speeds be estimated whereupon air flow can be evaluated. Another method is the air exchange method. In this method, tabulated values of the number of air changes occurring per hour are used for typical residential rooms. Typical air exchange values are given in Table VI. Note that an air exchange rate of 1.0 per hour indicates that the air flow into the room per hour equals the volume (length x width x height) of the room.

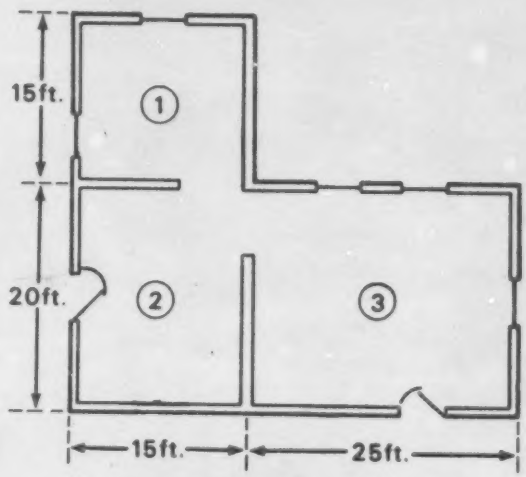

FIGURE 11. Plan view for infiltration volume illustration.

In residential construction the air exchange method is sufficiently accurate for infiltration volume calculations and is much simpler than the crack length and width method. Thus, the air exchange method will be used exclusively in this text.

EXAMPLE NO. 4

To illustrate the air exchange method, estimate the infiltration air volume for the simple house plan show in Figure 11, if the ceiling height is 8 feet and if the windows are not weatherstripped or storm sashed.

The infiltration air volume for each room is estimated by the formula:

Infiltration volume = Q_i = Air exchanges x room volume

For room (1): Q_i = 1.5 (15x15x8) = 2700 cu. ft/hr
For room (2): Q_i = 1.0 (15x20x8) = 2400 cu ft/hr
For room (3): Q_i = 2.0 (20x25x8) = 8000 cu ft/hr
For whole house: Q_i = 2700 + 2400 + 8000 = 13,100 cu ft/hr

Once the estimate of the volume of infiltration air is obtained, the energy required to heat or cool the air to the temperature of the living area can be calculated by the formula:

$$q_i = (0.018)\ Q_i\ (t_o - t_i) \ . \ .$$

(Equation 10)

Infiltration heat losses can now be illustrated by considering the house in Figure 11 and equation 10. The infiltration heat loss will be calculated when the outside temperature is 10°F and the living area temperature is 65°F.

$$q_i = (0.018)\ Q_i\ (t_o - t_i)$$

$$= 0.018\ (13,100)(65-10)$$

$$= 12,970 \text{ Btu/hr}$$

Notice that by weatherstripping the windows or adding storm windows, the infiltration heat loss could be reduced by 1/3, or

$$q_i = 2/3\ (12,970) = 8,650 \text{ Btu/hr}$$

4. VENTILATION HEAT LOSSES OR GAINS

The heat losses and gains due to ventilation air are evaluated in the same manner as infiltration heat losses and gains except the volume of air entering the building is different. That is

$$q_v = 0.018\ (Q_v)\ (\Delta t) \ . \ . \ .$$

(Equation 11)

where q_v = ventilation heat loss or gain, Btu/hr
Q_v = ventilation air volume, cu ft/hr

The ventilation air volume for residences is usually very small as compared to infiltration air volume.

Table VII gives typical ventilation air volumes.

In most single family residences the air exchange obtained by infiltration satisfies the ventilation requirements. If this is the case, the ventilation heat loss or gain is taken care of in the infiltration heat loss calculation. If supplemental ventilation is provided, simply determine the volume of air introduced by the ventilating fans, Q_v, and substitute Q_v into Equation 11.

5. RADIATION HEAT LOSSES OR GAINS

Radiation heat flow is far more important in cooling applications during warm weather than in heating applications during cold weather. Thus, our primary concern will be to estimate solar radiation heat gains during warm weather.

Solar radiation heat gains in residences may be conveniently divided into two categories:

a. Opaque Exterior Surfaces.
b. Windows and Transparent Surfaces.

a. Opaque Exterior Surfaces

When solar radiation strikes a building roof or wall, it increases the temperature of the building surface to a level above the outside temperature. The increased surface temperature thus changes the temperature difference between the inside and outside wall surfaces. Recalling the conduction heat transfer equation, $q_c = UA\ (t_o - t_i)$, an increase in t_o would increase the conduction heat transferred through the wall or roof.

A convenient method for accounting for the solar radiation heat load in a building is to use an equivalent air temperature called the sol-air temperature. Sol-air temperature is the equivalent outdoor air temperature which would yield the same heat transfer through a wall by conduction alone as that transferred due to the conduction heat transferred under the actual outdoor temperature and solar radiation. By using the sol-air temperature, t_e, instead of the actual outdoor temperature, t_o, the combined conduction and radiation heat transferred through opaque surfaces is estimated by equation (12):

$$q_{cr} = UA\ (t_e - t_i) \quad \text{. . (Equation 12)}$$

The design sol-air temperature is dependent upon the solar radiation intensity. Thus, sol-air temperatures are dependent upon the time of the year, geographical location, the orientation of the surface (N, S, E, W), the inclination of the surface (horizontal or vertical), and the color of the wall. The wall color is significant since dark colored walls absorb larger quantities of solar radiation, whereas lightly colored walls tend to reflect a large portion of the incident solar radiation. Typical values of sol-air temperatures are given in Table VIII for a latitude of 40°N on July 21.

Table VIII illustrates vividly the effects of surface color, orientation and inclination upon sol-air temperatures. For example, at solar noon, when outside air temperature equals 90°F, sol-air temperatures of vertical surfaces varied from 96 to 112°F dependent upon orientation. At the same time the dark colored vertical surfaces experienced sol-air temperatures between 103 and 134°F. Comparison of sol-air temperatures for horizontal surfaces at solar noon indicates a difference of 172-127°F, or 45°F, between dark and light colored surfaces.

EXAMPLE NO. 5

Estimate the total heat transferred through an 8' x 10' vertical wall section at 4 p.m. on July 21. Assume the wall has an overall heat transfer coefficient of 0.02, west facing orientation, is lightly colored, and is located at 40°F latitude. Also assume an inside air temperature of 75°F and an outside air temperature of 94°F.

$$q_{cr} = UA\ (t_e - t_i)$$

$$= 0.02(8x10)(131-75)$$

$$q_{cr} = 89.6 \text{ Btu/hr}$$

b. Windows and Transparent Surfaces

Solar radiation affects the heat gain through transparent surfaces in two ways. First, the combined conduction heat transferred is increased by the surface heating of the outside of the glass. Thus, the heat transferred by conduction is a function of the difference between sol-air temperatures and inside air temperatures. Second, is the solar heat gain inside the room by transmission. In summary, the total heat gain through glass areas equals the heat flow due to indoor-outdoor temperature differences plus the radiation transmitted through the glass.

The heat gain due to conduction is dependent upon the sol-air temperature, the indoor temperature, the overall heat transmission coefficient of the glass and the glass area. The solar heat gain by transmission is dependent upon the intensity of solar radiation, the orientation of the glass area with respect to the North, the degree of shading and the transmission coefficient of the glass.

6. ENERGY LOSSES AND GAINS FROM EQUIPMENT OPERATION

Heat is given off by many appliances and equipment, such as refrigerators, stoves, washing machines, dryers, freezers, dishwashers and lighting fixtures. This energy should be considered as advantageous to heating and may even reduce the size of your heating system. On the other hand, heat producing equipment adds to the cooling load.

UNIT II SITE SELECTION

COMPETENCY 1. Using a compass

LEARNING STEPS:

1. Understand the theory of a compass
2. Know the parts of a compass
3. Use the compass to locate North, South East and West.

LEARNING ACTIVITIES:

1. Attend teacher presentation on the compass
2. Read the Chapter The Compass in Elementary Surveying, 5th Edition, pp 159-165. Note and list mistakes on pp. 169.
3. Determine and show on a sketched world map, the difference between true north and magnetic north.
4. Operate a compass by lining up the needle with the north marking on the face.
5. Practice locating objects on the school campus geographically with the compass.

EVALUATION:

Given only a compass, identify and record on a drawing the magnetic location of doors and windows in the school building.

UNIT II SITE SELECTION

COMPETENCY 2 Matching building site to house plan

LEARNING STEPS:

1. Locate and determine direction of winds.
2. Locate and determine path of sun.
3. Geographically orient structure.
4. Locate access route to structure.

LEARNING ACTIVITIES:

1. Attend teacher presentation on prevailing wind and path of sun.
2. Read Information Sheet II-2-1 "What Site to Choose."
3. Answer questions on Study Guide.
4. Mark the magnetic poles with markers on a building location.
5. Locate and mark the direction of the prevailing winds on a building site.
6. Identify the sun's path on a building site.
7. Orient the house to take maximum advantage of the sun, and minimize the effects of the wind.
8. Lay out the access route to structure.
9. Select a desirable site for constructing a building and explain the reasons why.

EVALUATION:

Given a plot plan and several house plans, select and orient a house to optimize the sun and minimize the wind.

INFORMATION SHEET II-2-1

What Site to Choose

Wherever you choose to live or work, you cannot help but experience the weather--sunshine, wind, rain, temperature and humidity. These elements of climate along with the geography, or nature of the land and vegetation around us, should determine how we select a building site to obtain maximum comfort and efficiency. To save energy, some residences are now constructed underground.

From this section, you will be able to describe how climatic conditions and geographic location may affect your choice of building sites. A discussion of climate and its effects will follow under these headings:

1. Types of Climate.
2. Effect of Climate and Geographic Location.
3. Effect on Convenience.
4. Effect on Energy Use.

1. TYPES OF CLIMATE

Webster's Dictionary defines climate as "the average course or condition of the weather at a place over a period of years..." Since weather is the momentary state of the atmospheric environment at a particular location, climate could be defined as the sum total of all the weather that occurs at any place.

Wind, precipitation, sunlight, temperature, and humidity are all factors of the weather. Combinations of these elements give each climate zone its normal weather characteristics.

A review of the climatic conditions in the U. S. will be helpful. The United States is typically divided into four climatic zones: cold, temperate, hot-arid, and hot-humid. The areas of the United States which exhibit the general characteristics associated with each zone are shown in Figure 2. The boundary between regions is not as abrupt as indicated. Climatic characteristics vary both between and within regions. It is not unusual for one region to exhibit at one time or another the characteristics common to every other region.

Cold regions: A wide range of temperature is characteristic of cool regions. Temperatures of minus 30°F (-34.4°C) to plus 100°F (37.8°C) have been recorded indicating hot summers and cold winters. Persistent winds year round are generally out of the NW and SE. Northern locations with cool climates receive less sunshine than southern locations.

Temperate regions: Seasonal temperatures provide an equal distribution of overheated and underheated periods. Seasonal winds from the NW and S along with periods of high humidity and large amounts of precipitation are common. Intermittent periods of sunny days are followed by extended periods of cloudy, overcast days.

Hot-arid regions: Hot-arid regions are characterized by clear sky, dry atmosphere, extended periods of overheating, and wide day to night temperature range. Wind direction is generally along an E-W axis with day and evening variations.

Hot-humid regions: High temperatures and frequent rains are characteristic of hot-humid regions. Wind velocities and direction vary throughout the year and during the day. Hurricanes with wind velocities up to 193 km/h (120 mph) may be expected from E-SE directions.

2. EFFECT OF CLIMATE AND GEOGRAPHIC LOCATION

The effect of climate on building location is very important. Of primary concern is the orientation of the building to make the best use of solar radiation and wind direction.

The "sol-air" effect recognizes that solar radiation and outdoor temperature act together to influence the overall heat gain through the surfaces of a building. Since the outdoor air temperatures are lower in the morning and peak in the mid-afternoon, a house should be oriented somewhat east of due south in order to take advantage of the early morning sun when heat is most needed. In the summer, the principal heat gain comes in the afternoon, from the west and southwest, so the house should face away from this direction to minimize the solar heat gain in that season. The optimum orientation will vary for different regions and building sites depending upon heating and cooling needs and other factors such as the wind.

3. EFFECT ON CONVENIENCE

You may be limited in choice as to the geographic location of the building. However, you may be able to select a site that will give you the benefit of natural resources. Look for the following site characteristics:

- Advantage of sunlight.
- Advantage of shade.
- Advantage of prevailing winds.
- Protection from cold winds.

4. EFFECT ON ENERGY USE

Naturally you will use more energy in heating a building in cold climates. In warm climates, the energy used for air conditioning may be more than for heating.

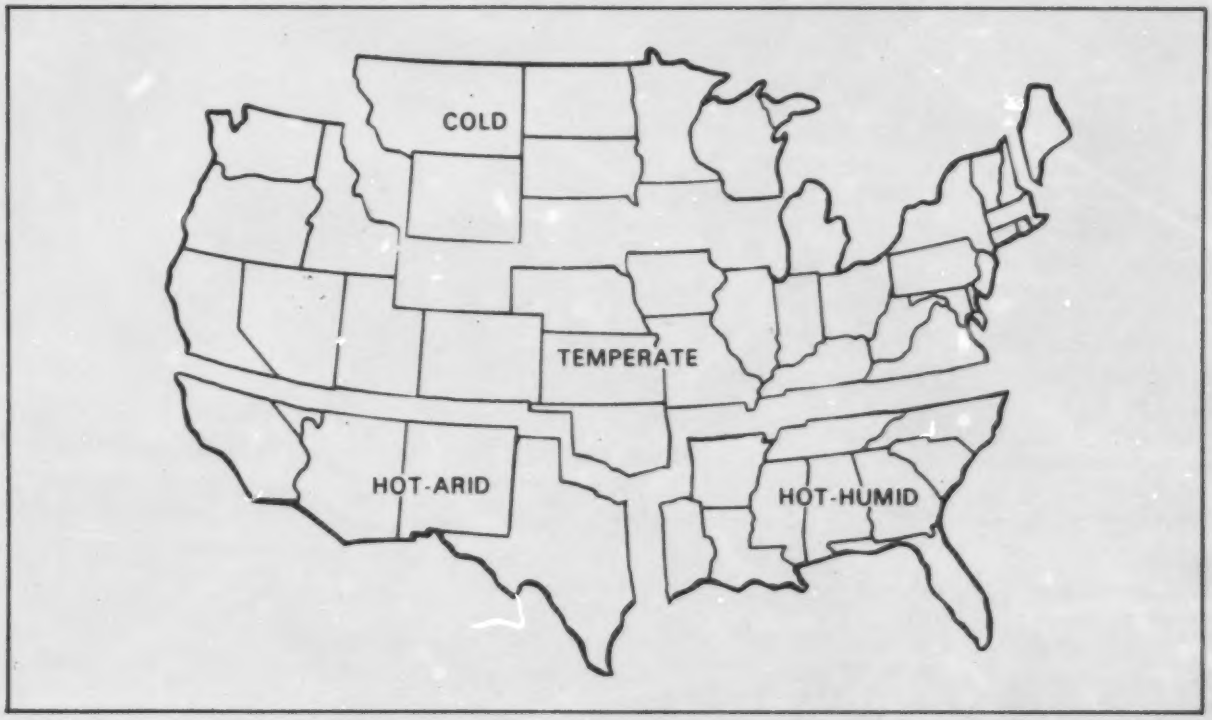

FIGURE 2. Climatic regions of the conditions in the United States.

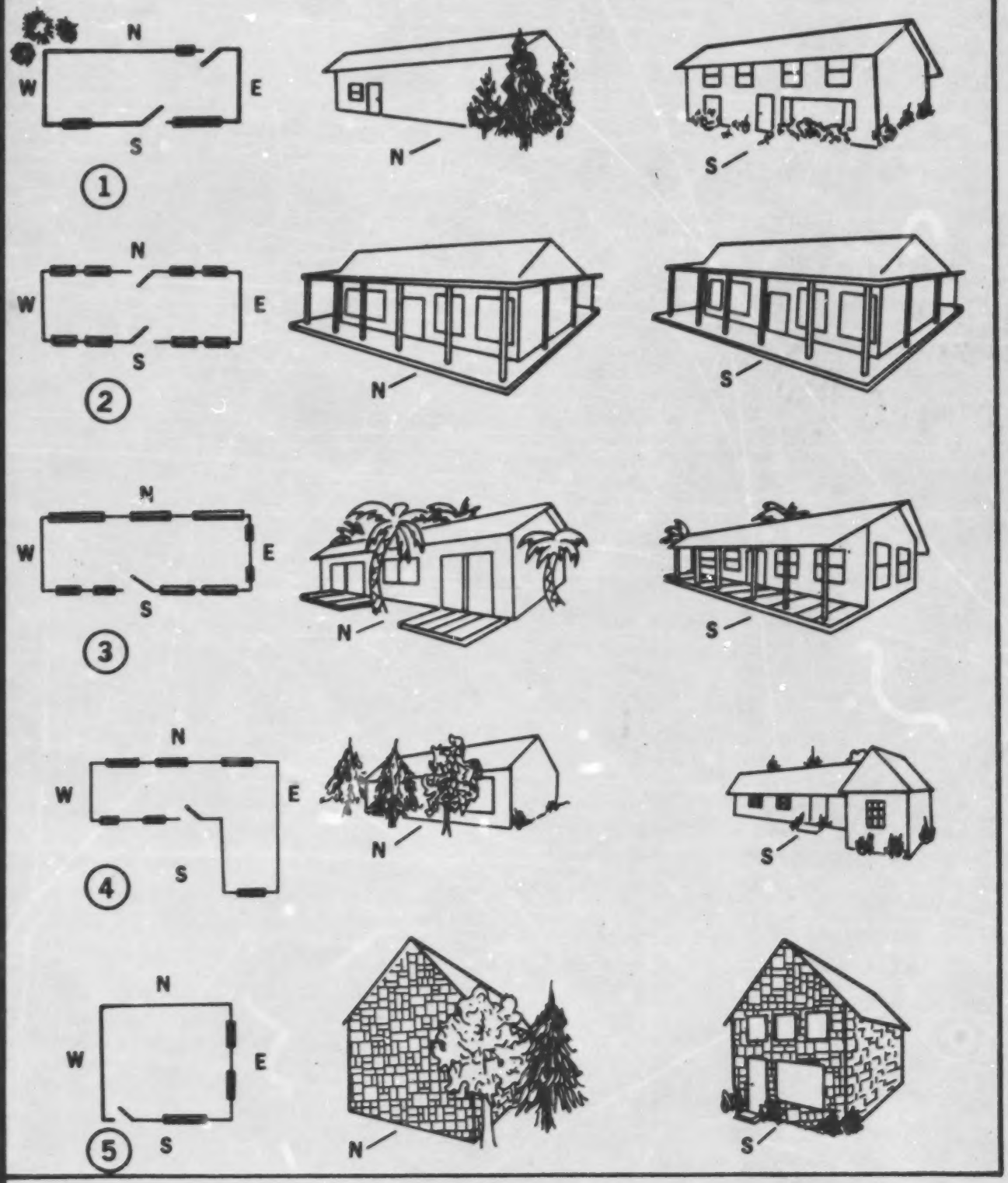

FIGURE 1. (Continued on next page)

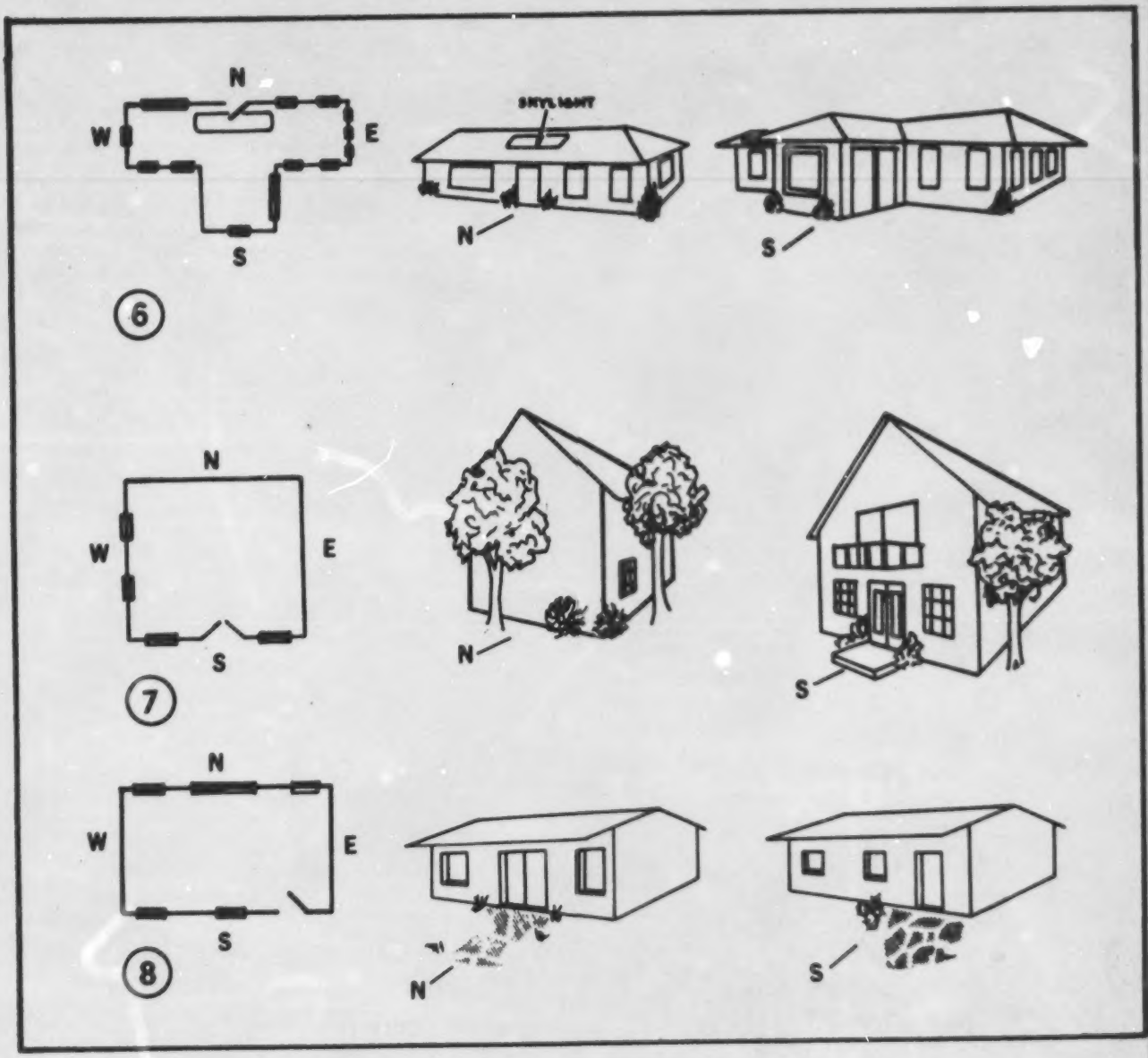

FIGURE 1. (Continued from preceding page)

STUDY GUIDE II-2-1

Circle the letter(s) that represent the correct answer(s), unless instructed otherwise.

1. Factors influencing site location for energy efficiency include:

   a. Sunshine.
   b. Wind.
   c. Rain.
   d. Temperature.
   e. Humidity.
   f. All of the above.

2. Climate is a major factor in energy requirements for buildings.

   a. True.
   b. False.

3. Match the following climatic zones in the U.S.:

   a. Cool.
   b. Temperate.
   c. Hot-arid.
   d. Hot-humid.

   1. __Southeast.
   2. __North Central.
   3. __Middle.
   4. __Southwest.

4. In Figure 1, indicate the climatic zone recommended for each building orientation for energy efficiency.

   a. Cool.
   b. Temperate.
   c. Hot-humid.
   d. Hot-arid.

   __1
   __2
   __3
   __4
   __5
   __6
   __7
   __8

5. Match the following advantages as to site location.

   a. Sunshine.
   b. Shade.
   c. Prevailing winds.

   1. __Cold.
   2. __Hot.
   3. __Humid.

6. Places to get help and advice on energy saving techniques are:

   a. Energy Extension Office.
   b. Cooperative Extension Service.
   c. Colleges of Engineering and Technology.
   d. Private architects.
   e. Utility companies.
   f. All of the above.

UNIT II

ANSWER KEY II - 2-1

1. F
2. A
3-1. D
2. A
3. B
4. C
4-1. C
2. C
3. C
4. B
5. A
6. B
7. A
8. D
5-1. A
2. B
3. C
6. F

UNIT II SITE SELECTION

COMPETENCY 3: Determining Landscape Potential

LEARNING STEPS:

1. Understand the differences between deciduous and conifer trees.
2. Locate vegetation to block wind
3. Contour the earth to block wind
4. Locate trees to provide shade
5. Utilize vegetation to control humidity
6. Identify sources of potential moisture problems

LEARNING ACTIVITIES:

1. Attend teacher presentation on landscape potential.
2. Read pages 19-27 in Earth Sheltered Housing Design
3. Read from available text to determine types and characteristics of trees.
4. Divert air flow from fan or air duct to show effectiveness of wind breaks.
5. Block heat from available heat source to show effectiveness of shading-and heat collection.
6. Locate a house on a provided plot plan.
7. Locate deciduous trees to shade house from sun on south and west sides.
8. Locate shrubs and trees to block wind, to control humidity, and prevent the the driveway from becoming a breezeway.
9. Show on a plot plan landscaping to control potential moisture problems.

EVALUATION:

Given a house located on a plot plan, determine landscape potential for maximum energy efficiency.

UNIT III
FOUNDATION CONSTRUCTION

COMPETENCY 1 Select an energy efficient foundation

LEARNING STEPS:

1. Define the basic types of foundations.
2. Determine climates in which these various types are used.
3. Determine the most effective foundation for each type of soil.
4. Determine the most energy efficient type of foundation for the building site.

LEARNING ACTIVITIES:

1. Attend teacher lecture on the basic types of foundations.
2. Refer to Information Sheet I-2-1 "Energy Efficient Structural Design Features."
3. Refer to and read American Plywood Association, P. O. Box 11700, Tacoma, WA 98411 Publication A400 "All-Weather Wood Foundation System."
4. View filmstrip program "Residential Architecture" Module 1 Excavation and Masonry, Robert J. Brady Company, A Prentice Hall Company, Bowie, Maryland 20715
5. View slide set "Light Construction Techniques," Foundations 2, Howard W. Sams and Co., Inc. 4300 West 62nd Street, Indianapolis, IN 46268
6. View 16 mm film "The Foundation" Circle Oaks Productions, Girdle Ridge Drive, Katonah, NY 10536

EVALUATION:

Select the appropriate energy efficient foundation for the given geographical area and soil condition.

INSTALLING INSULATION IN THE BASEMENT AND CRAWL SPACE

If a building has a crawl space, the floor above the crawl space can be insulated and the crawl space ventilated or the crawl space itself can be insulated. Good insulation is especially necessary in a crawl space or basement if the crawl space contains heating ducts for the furnace.

Insulating basements and crawl spaces is discussed under the following headings:

a. Flexible Insulation.
b. Loose-Fill Insulation.
c. Rigid Insulation.
d. Reflective Insulation.

Flexible Insulation

Basements and crawl spaces in wood framed houses have one part of the structure that is often not insulated. This area is the band joist. Normally at this point there will be only 3.8 cm (1 1/2 in) of lumber plus whatever is used as a siding on the outside. This is usually corrected by stapling flexible insulation in the space between the floor joists (Figure 90).

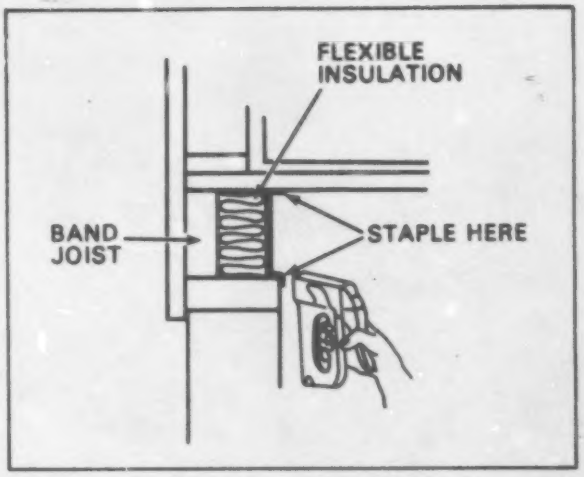

FIGURE 90. Insulate the band joist.

In addition to using flexible insulation at the band joist, it may also be used between furring strips if the basement is finished (Figure 91). In a crawl space, the batt can be stapled to the foundation wall and brought down to the vapor barrier on the ground (Figure 92).

In wood foundations, insulation is installed exactly as it is in any other stud wall.

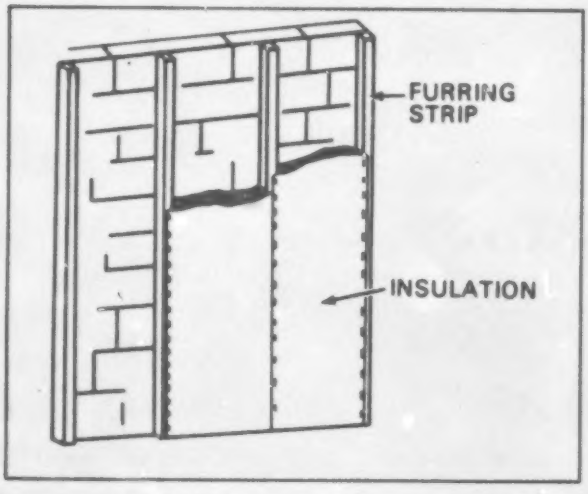

FIGURE 91. Furring strips may be added to a masonry wall to provide for flexible insulation.

UNIT III
FOUNDATION CONSTRUCTION

COMPETENCY 2: Select energy efficient foundation insulation.

LEARNING STEPS:

1. Identify available foundation insulation materials.
2. Determine desirable characteristics of foundation insulation materials.
3. Compare initial costs of R value per square foot
4. Determine if the insulation is to be installed on the inside or outside of the foundation.
5. Select the most desirable foundation insulation.

LEARNING ACTIVITIES:

1. Attend a lecture presented by your instructor on "Foundation Insulations".
2. Define the following terms: compression strength, water resistant, water absorbent, R value stability, and tongue and groove configuration.
3. Attend a presentation by a local commercial roofing, waterproofing contractor.
4. Read pp 145-147 in Earth Sheltered Housing Design.
5. Answer questions on Study Guide III-2-1

EVALUATION: Given a house plan including climate and terrain information, select the type, amount, and method for installing foundation insulation that is the most energy efficient.

UNIT III

FOUNDATION CONSTRUCTION

COMPETENCY 3: Match waterproofing methods to moisture problems.

LEARNING STEPS:

1. Understand the difference between waterproofing and damp-proofing methods.
2. Become familiar with drainage techniques in the waterproofing system.
3. Identify various waterproofing methods.
4. Approximate the cost per square foot of various waterproofing systems.
5. Match waterproofing methods to moisture problems.

LEARNING ACTIVITIES:

1. Listen to guest speaker or instructor's lecture on waterproofing, damp-proofing, and drainage techniques.
2. Read pp. 131-144 in Earth Sheltered House Design.
3. Visit a construction site and view a waterproofing application.
4. Contact a roofing/waterproofing contractor for professional expertise to assist in estimating costs per square foot for various waterproofing applications.

EVALUATION:

Given 3 house plans with climate information and soil conditions, plot a drainage system and describe a waterproofing method. Contour the earth around the structure to eliminate as many moisture problems as possible.

STUDY GUIDE III-2-1

Circle letter representing correct answer, unless instructed otherwise.

1. Insulation should be placed in the crawl space walls:

   a. If the floor is insulated.
   b. To prevent rats and mice from entering.
   c. If the floor is not insulated.

2. What types of insulation should be used in the crawl space?

   a. Flexible.
   b. Loose-fill.
   c. Rigid.
   d. Reflective.

3. Place the vapor barrier:

   a. On the side next to the foundation wall.
   b. On the ground surface of crawl space.

4. When insulating the crawl space, never insulate the band joist.

   a. True.
   b. False.

5. If heating and cooling ducts are in the basement, it is not necessary to insulate the basement walls.

   a. True.
   b. False.

6. On masonry walls, flexible insulation:

   a. May be attached to furring strips on the foundation wall.
   b. May be used to fill cores of concrete blocks.
   c. May be stapled to concrete block.

7. Loose-fill insulation is used only to pour into cores of concrete blocks.

   a. True.
   b. False.

8. Rigid insulation may be glued to masonry walls.

   a. True.
   b. False.

UNIT III
STUDY GUIDE III-2-1

Answer Key

1. C
2. A
3. B
4. B
5. B
6. A
7. A
8. A

UNIT IV

FLOORS, WALLS AND CEILINGS

COMPETENCY 1: Select energy efficient doors

LEARNING STEPS:

1. Define the various types of doors.
2. Determine the insulating quality of each type of door.
3. Determine the effect of climate on selection of doors.
4. Determine ways to protect entries.
5. Select the most energy efficient door.

LEARNING ACTIVITIES:

1. Attend a teacher presentation on the various types of doors.
2. Read Information Sheet IV-1-1 "What Type of Doors to Use."
3. Define the various types of doors available.
4. Read Chapter 26 in Construction, Jack Landers Goodheart Wilcox Publishing Co., 1976.
5. Visit local suppliers and report on the types, availability, and costs of doors.
6. Attend a lecture/demonstration on energy efficient doors given by a representative of a door manufacturer.

EVALUATION:

Given a floor plan and climate conditions, select doors that will provide for maximum energy efficiency.

INFORMATION SHEET IV-1-1

What Type of Doors to Use

Aside from beauty and durability, exterior doors should be selected with their insulating quality in mind. Interior doors do not have this requirement.

Exterior doors in common use for most living spaces and commercial buildings are either of wooden or metal construction. Glass area varies in doors and can greatly affect the insulating value of a door. Metal frame doors with insulating glass, thermo-barriers, and good weatherseals can be as effective as storm doors. Fiberglass doors are just beginning to enter the market.

From this section, you will be able to describe the characteristics of doors under the following headings:

1. Types of Doors.
2. Effect of Climate.
3. Effect of Insulating Quality.
4. Effect on Energy Use.
5. Effect on Cost Benefits.

1. TYPES OF DOORS

Doors, like windows, affect heat loss and gain by both conduction and air infiltration. Once the air infiltration factor is solved with caulking and weatherstripping, the insulating value of the door becomes significant. Three main types of doors are used in light building construction. They are as follows:

a. Hollow-Core Doors

Most hollow-core doors used today consist of a solid wood frame with a veneer of birch, or mahogany. They are used mainly for interior doors but sometimes are used as an exit door to an attached garage.

b. Solid-Wood Doors

Solid-wood doors are commonly made from pine, oak, or maple.

c. Steel-Clad, Foam-Center Doors

Most modern builders use steel-clad exterior doors for building entrances or exits (Figure 36). These doors have a urethane foam insulating core.

To function as a good thermal barrier, doors need good weatherstripping and thresholds.

2. EFFECT OF CLIMATE

Doors need protection from the elements of weather to do their job most efficiently. Doors can do very little, however, to add heat from radiation as do windows. Their main job is to keep the cold air out. To remain in good condition, doors should be protected by overhangs, vestibules or storm doors. Placement on sides other than the north exposure will protect against most winter storms. Landscaping can provide shelter for entrances which would otherwise receive the full force of wind and snow.

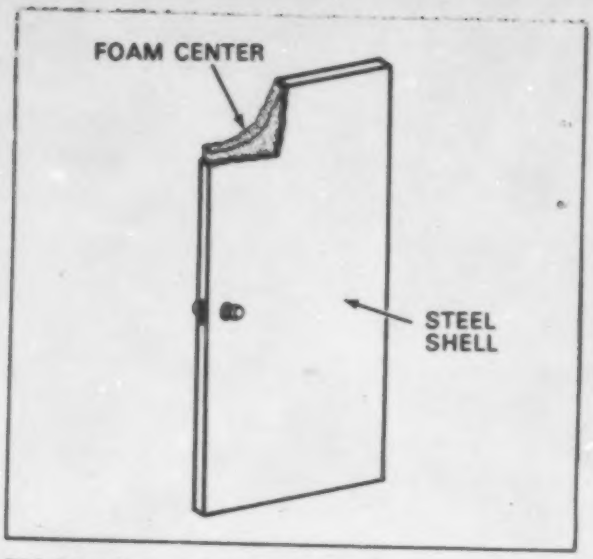

FIGURE 36. A steel-clad, foam-center door has good insulating quality.

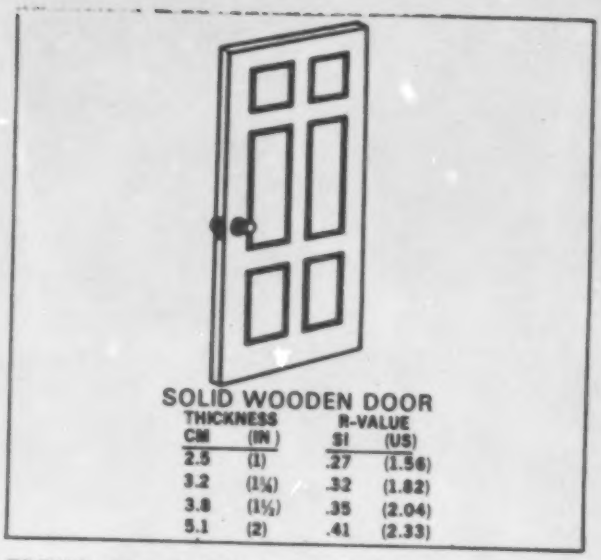

FIGURE 37. R-Values for solid wooden doors.

3. EFFECT OF INSULATING QUALITY

Doors have different insulating qualities. They are discussed as follows:

a. Solid Wood Doors

Wooden doors are usually solid core, or solid frame with panels. Solid-wood prime doors alone without storms would have R-Values as shown in Figure 37.

Wood frame doors with panels would have about 60% of the resistance values as a solid door.

b. Steel-Clad, Foam-Center Doors

Metal doors are usually sheet metal over a metal or wood frame with an insulation core. Metal-clad doors with an insulating core would have R-values as shown in Figure 38.

FIGURE 38. R-Values for steel-clad, foam-center doors.

c. Storm Doors

The most effective step in reducing heat loss through doors is to install a storm door. A wood storm door with about 50% glass area can reduce the heat loss by 45 to 50%. A metal storm door, regardless of the percentage of glass, will reduce the heat loss by only 30 to 35%.

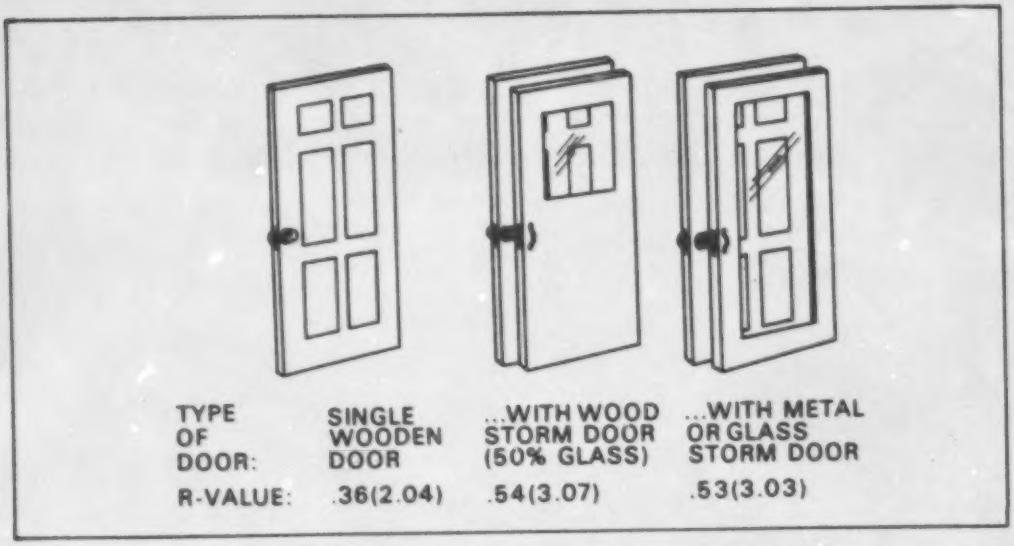

FIGURE 39. R-Values for different types of doors.

The type of storm door that has a wood frame with about an 80% glass area, to better display a prime door, has an insulating value similar to that of a metal storm door.

A comparison of various door arrangements and their R-Values is shown in Figure 39.

4. EFFECT ON ENERGY USE

The better insulated outside doors you have, the more energy you will save.

5. EFFECT ON COST BENEFITS

It pays to have well-insulated outside doors. In extreme climates, your money will be returned in savings on heating and cooling bills. Refer to Table IV for general recommendations.

Unit IV

FLOORS WALLS AND CEILINGS

Competency 2: Select Energy Efficient Windows

Learning Steps

1. Define primary and secondary windows.
2. Define various types of windows.
3. Define infiltration and condensation.
4. Determine ways to control condensation and infiltration.
5. Select the most energy efficient windows.

Learning Activities

1. Attend teacher presentation on various types of windows.
2. Read Information Sheet IV-2-1 "What Types of Windows to Use."
3. Read Chapter 25 in Construction, Jack Landers, Goodheart Wilcox Publishing Co., 1976.
4. Attend a lecture on energy efficient windows, given by a representative of a window manufacturer.
5. Visit local suppliers and report on the types, availability, and costs of windows.
6. Answer the questions on the Study Guide provided.

Evaluation:

Given a set of houseplans, select and place the most energy efficient windows to be used in the construction.

What Type of Windows to Use

There are several types of windows for both homes and commercial buildings. The type of window selected is a matter of owner/builder preference. The right window in the right place gives a home natural light, fresh air, good looks and convenience.

The major decision related to energy-saving, however, is the number of layers of glass to choose for a particular climate. There are choices between insulated glass or storm windows and even justification for triple glazing in some locations. From this section, you will be able to list the factors for selecting types of windows for energy efficiency.

1. Types of Windows.
2. Effect of Climate.
3. Effect of Insulating Quality.
4. Effect on Energy Use.
5. Effect on Cost Benefits.

1. TYPES OF WINDOWS

Builders have a choice of several types of windows. Window sash is made primarily of wood or metal with some plastics being used for weather protection. We will discuss both the prime windows and storm windows. The original (or inside) windows in a home are referred to as prime windows—the first windows. Storm windows are secondary windows.

The various types of prime windows used in houses and other small buildings are shown in Figure 30.

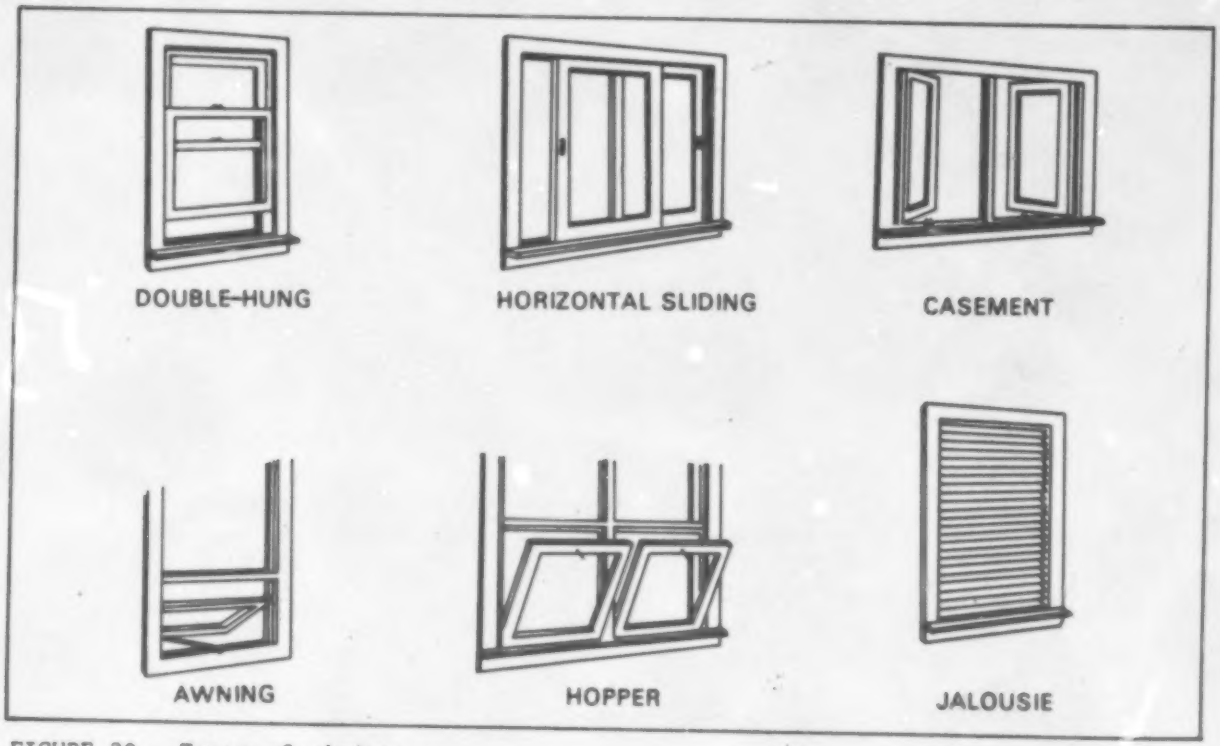

FIGURE 30. Types of windows.

a. Double-Hung Windows

The conventional double-hung window usually has two sashes which operate vertically. They are found in most homes and are adaptable to any architecture.

Double-hung windows usually have a separate wood or metal-frame storm window attached on the outside of the window casing. Metal-frame storm windows are lighter in weight and easier to handle. They are often sold as combination storm-screen units which allow for self-storing of the screen or second glass. The higher heat conductivity of metal, however, makes them about 20% less efficient than wood-frame units.

b. Horizontal Sliding Windows

The sashes in this type of window slide horizontally. Usually there are two movable sashes; sometimes one is fixed. These windows may be equipped with insulating glass, a conventional storm window attached to the outside frame, or a storm panel that attaches directly to the window sash.

c. Casement Windows

Casement windows swing outward on hinges attached at the side. A storm window must be attached directly to the sash or on the inside frame. If an inside storm is used, no ventilation is possible during the heating season.

d. Awning Windows

Hinged at the top, they are manufactured as a single unit or as several sashes stacked together in one frame. When open, the sashes project at an angle like awnings. Inside storm sash or storm panels must be used, with the same limitations as described for casement windows.

e. In-Swinging (Hopper) Windows

These can be either bottom-hinged hopper windows or top-hinged windows such as those often used in basements. They can be equipped with a storm sash on the outside or a storm panel attached to the prime window. Both out-swinging and in-swinging windows offer adjustable ventilation. When used with fixed-sash, they provide air flow for picture windows.

f. Jalousie Windows

A series of small horizontal glass slats make up a jalousie window. They are held by an end frame, pivot in unison like a venetian blind and open outward. Jalouise windows are not satisfactory as prime windows for an area to be heated as they are very difficult to seal, even with the use of a storm panel on the inside.

2. EFFECT OF CLIMATE

Our elements of weather—sunshine, temperature, wind, moisture—must all be considered when selecting and placing windows.

Since windows are a source of heat gain and loss, we will want to place windows on the south and southeast side to receive solar radiation for warming in the winter and to avoid cold winds from the north-northwest.

Glass is a good conductor of heat; therefore, the greater the temperature difference between the interior and exterior surfaces of the glass the greater the heat loss or gain. Extremes in temperature require the use of insulating air spaces between two or more layers of glass to make windows less conductive.

The infiltration or air leakage around a window frame or sash is also affected by temperature and moisture. Wood reacts to moisture variations by swelling or shrinking. The result is a crack or space around the window or frame for air to leak in or out.

Condensation is another problem. The source of condensation, or "sweating" on windows is humidity, or invisible water vapor in the air. A cold window surface allows the water vapor in the air to condense rather than be absorbed. By "insulating" our windows through the use of storm windows or thermo-layers, we increase the inside temperature of the glass surface and reduce condensation. Humidity control within the building is also an important factor.

3. EFFECT OF INSULATING QUALITY

In a well-insulated house with as little as 10% of the wall area in glass, as much as 25% of the total heat loss may be through the glass. In the summer, glass admits the radiant energy of the sun which is converted into heat. Storm windows or multi-pane windows reduce the heat loss or gain by more than half (Figure 31). They are discussed as follows:

a. Storm Windows

Storm windows are usually more efficient and economical than insulating glass (factory sealed) for the following reasons:

- The storm window provides a separate seal of the cracks around the window.
- The air space between the two layers of glass is greater, providing more insulation.
- Using a storm window does not require replacement of good prime windows to obtain an insulating sash.

FIGURE 31. R-Values for window with storm sash or double-insulated glass.

b. Multi-Pane Windows

Multi-pane windows are sometimes referred to as insulated windows. They have two or more panes of glass with an air space between.

For additional insulation, add a storm window to a double pane glass or use triple glazing.

Triple glazing (insulating glass plus a separate storm sash, or new factory-sealed triple unit) can often be justified in areas with 6,000 or more seasonal degree days in houses that are also centrally cooled. They may also be justified when using electric heating. Figure 32 illustrates the R-values for triple glazing.

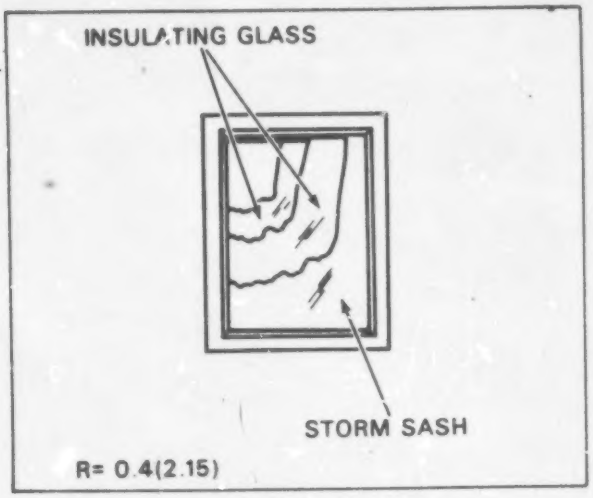

FIGURE 32. R-Values for triple glazing.

Triple glazing is also an effective barrier for noise and is sometimes used for this reason alone in houses near airports, for example.

An increase in comfort for room occupants usually accompanies the use of storm windows or insulating glass. This fact is illustrated in Figure 33 which shows the dramatic increase in the inside temperature of the surface when two or more layers of glass are used.

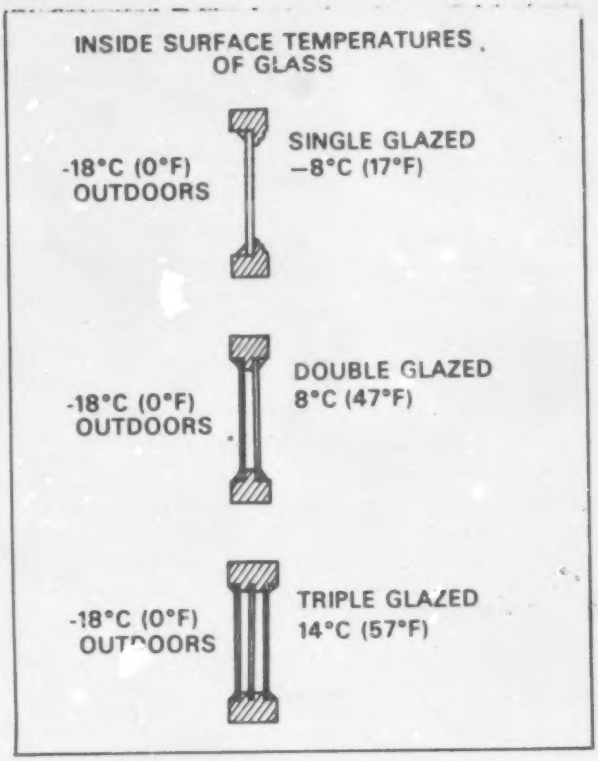

FIGURE 33. Inside temperatures of glass for single-glazed, double-glazed and triple-glazed windows.

The problem of moisture condensation can be almost eliminated with the use of insulating glass and storm windows and weep holes. When the outdoor air is 22°C (0°F), moisture condensation will occur on the glass when the relative humidity inside the house is only 12%. With insulating glass, condensation will not occur until the relative humidity is 30%. With insulating glass and a storm window, condensation will not occur until the relative humidity is 37%.

4. EFFECT ON ENERGY USE

It has already been stated that windows can be the biggest cause of home energy loss. They may be costing a home or building owner up to a third of his heating and air-conditioning expense.

STUDY GUIDE IV-?-1

Circle the letter(s) that represent the correct answer(s), unless instructed otherwise.

1. Types of windows are as follows:

   a. Double hung.
   b. Horizontal sliding.
   c. Casement.
   d. Awning.
   e. All of the above.

2. Aluminum-frame windows have a lower R-value than wooden frame windows.

   a. True.
   b. False.

3. Jalousie windows are energy efficient.

   a. True.
   b. False.

4. Window space in a building:

   a. Improves energy efficiency.
   b. Reduces energy efficiency.
   c. Makes no difference in energy efficiency.

5. To improve the efficiency of windows:

   a. Add storm windows.
   b. Install triple glazed windows.
   c. Add plastic sheeting.
   d. None of the above.

6. Windows may lose energy by:

   a. Excessive heat conduction.
   b. Infiltration.
   c. Improper shades and drapes.
   d. Improving R-value.

7. Windows help prevent infiltration.

   a. True.
   b. False.

UNIT IV

ANSWER KEY IV -2

1. E
2. A
3. B
4. B
5. A, B, C,
6. A, B, C,
7. B

UNIT IV

FLOORS, WALLS AND CEILINGS

COMPETENCY 3: Select Energy Efficient Weatherstripping and Caulking.

LEARNING STEPS:

1. Define the various types of weatherstripping and caulking.
2. Determine the insulating quality of each type of weatherstripping and caulking.
3. Determine the effect of climate of each type of weatherstripping and caulking.
4. Select the appropriate weatherstripping and caulking.

LEARNING ACTIVITIES:

1. Attend a teacher presentation on the types and uses of weatherstripping and caulking.
2. Read Information Sheet IV-3-1 "What Type and How Much Weatherstripping and Caulking to Use."
3. Define the various types of weatherstripping and caulking.
4. Visit local suppliers and report on the types, availability and costs of weatherstripping and caulking.
5. Answer the questions on Study Guide IV-3-1.
6. Read Information Sheet IV-3-2 "Installing Weatherstripping and Caulking."
7. Answer the questions on Study Guide IV-3-2.

What Type and How Much Weatherstripping and Caulking to Use

Weatherstripping and caulking can have dramatic results in terms of both comfort and energy saving. These are two jobs that home or building owners (or renters) can do themselves and at little cost.

Weatherstripping and caulking are perhaps the most important jobs you can do to save energy in buildings.

Weatherstripping is placed around windows and doors in such a way that they can close more tightly than before, yet can still be opened. Weatherstripping is usually applied with either nails or glue. Sometimes it is self-adhesive, with a paper peel-off back.

There are many different kinds of weatherstripping on the market, most of which do an adequate job. You will want to choose weatherstripping on the basis of ease of application, appearance and expense.

Caulking is used to fill cracks around the frames of windows and doors. It can seal cracks under eaves (if not for ventilation), around flashing, between bricks and in basement walls.

The ideal caulking will adhere to both sides of the opening to be closed and remain resilient to permit movement between the two materials without cracking. Usually the more expensive caulkings do a better job of sealing and last longer.

From this section, you will be able to describe the types of weatherstripping and caulking and explain how they can be used to make buildings more energy-efficient. This information is presented under the following headings:

1. Types of Weatherstripping and Caulking Available.
2. Effect on Energy Use.
3. Effect on Cost Benefits.

1. TYPES OF WEATHERSTRIPPING AND CAULKING AVAILABLE

Weatherstripping and caulking are described under the following headings:

a. Weatherstripping.
b. Caulking.

a. Weatherstripping

Of the several types of weatherstripping, all are available to the consumer (Table V). Although different situations call for different types of material, most can be used for either doors or windows.

Types of weatherstripping include felt-fabric strips, metal strips, and wide, flexible weatherstripping for garage doors.

There is transparent weatherstripping which is pressed on to the outside of the window along the frame and trim. There is flexible, putty-like material that is easy to apply and suitable for windows which are rarely, if ever, opened, such as in the attic or basement.

For outdoor entrances, there are special strips of plastic that are attached to the bottom of each door itself. They're called threshold sweep strips. There are also metal thresholds with gasket strips which are usually screwed into place.

Some weatherstripping depends upon the compression of a resilient material between one or two moving surfaces; others depend upon a mechanical interlocking of two parts. Table V lists the types of weatherstripping and their characteristics.

b. Caulking

Although the air leaks around windows and doors can be sealed with weatherstripping, other cracks can exist which allow the passage of heated or cooled air. Caulking is used to seal cracks between similar or dissimilar building materials. Cracks between two different materials are called "moving joints" because the joint expands and contracts due to the fact that different materials expand and contract at different rates depending on changes in temperature, moisture, or pressure.

A number of small cracks can add up to a lot of leakage, which is energy lost. Moisture can enter and cause rotting. Insects and other pests can also enter and cause problems. Thus, caulking is sometimes just as important as weatherstripping.

Caulking comes in several forms (Table VI). The most popular is the cartridge due to its ease of application with a caulking gun. Caulk also comes in squeezable tubes as well as cans for application with a putty knife. Another type is called rope caulk because it consists of strands of caulk packaged in a roll.

Buying caulk in bulk is most economical for industrial users or contractors. However, since shelf life is short, the homeowner should buy only the amount that will be used in one season.

Table VI lists the types of caulk and their various characteristics.

2. EFFECT ON ENERGY USE

A crack or crevice that allows air to pass reduces the effectiveness of your insulation. Weatherstripping and caulking will increase the efficiency of your building.

3. EFFECT ON COST BENEFITS

You can't go wrong on spending money for weatherstripping and caulking. You will save enough on energy bills to recover it.

TABLE V. CHARACTERISTICS OF DIFFERENT TYPES OF WEATHERSTRIPPING

Type of Weatherstripping	Material/Form	Advantages	Problems	Cost
Pressure-Sensitive, Adhesive-Backed Foam	Polyurethane foam with vinyl cover in roll OR closed-cell vinyl foam.	Easy to install. Cushioning effect--noise reduction in closing. Good seal.	Avoid painting--causes loss of resiliency. 1-3 yr life--not durable. More effective on doors.	Low to medium.
Metal Spring Self-Sticking	Bronze, copper, stainless steel, or aluminum. V-shaped or single roll strip.	Excellent seal. Very durable. Easy to install.	Requires patience for installation.	Medium.
Felt or Self-Sticking	Variety of widths and thicknesses in a roll.	Easy to install. Various colors.	Variable life--may stick to door finishes.	Low.
Serrated Metal	Felt or vinyl-backed metal roll.	Easy to install.		Medium.
Tubular Gasket (rolled vinyl) Foam-Filled Tubular Gasket	Flexible vinyl in tubular form with or without metal backing.	White or gray. Easy to install. Very good, durable seal.	Cannot be painted or it will lose flexibility. Extra strength, holds shape. Extra insulating value.	High.
Interlocking Metal	Two interlocking pieces--strip.	Tight seal. Best available for doors.	Difficult to install due to alignment and cutting. Maintenance requires straightening of bent pieces.	High.
Casement Window Gasket	Vinyl roll.	Easy to install--slip on lip of window.	Gray only.	Medium.

TABLE V. CHARACTERISTICS OF DIFFERENT TYPES OF WEATHERSTRIPPING (CONTINUED)

Type of Weatherstripping	Material/Form	Advantages	Problems	Cost
Jalousie Gaskets	Clear vinyl. U-shaped track.	Easy to install-slip on.		Medium.
Door Sweeps	Wood and felt or wood and foam or metal and vinyl strips.	Easy to install. Effective seal against drafts.	Must clear carpet.	Medium.
Thresholds	Vinyl insert in metal base strip OR two-piece interlocking strip.	Generally best seal for exterior doors.	Often requires removal of old threshold or cutting of door.	High.

TABLE VI. CHARACTERISTICS OF DIFFERENT TYPES OF CAULKING

Type of Caulk	Advantages/Application	Problems/Solutions	Cost
Oil Base	Adheres to most surfaces--prime porous surfaces.	Not for use on moving joints. As oil dries out, caulk shrinks; 1 to 7 year life--prolong life by painting after drying.	Low
Latex Base	Long life up to 10 years (some are guaranteed for 20 years). Adheres well to most surfaces--prime or paint metal and porous surfaces. Dries quickly. Can be painted in 15-30 minutes--accepts most paints.	Shrinks some--apply a big bead of caulk and use it to fill only narrow cracks.	Medium
Butyl Rubber	Should last up to 10 years if properly applied. Can be applied indoors or out, on metal or masonry. Can be painted with any type of paint after curing for a week.	Shrinks a little--apply a wide bead and cover only small cracks.	Medium
Polyvinyl Acetate (PVA)		Loses flexibility when it dries--use only for small holes indoors.	High
Silicone Seal	Excellent sealant--can last for at least 20 years. Adheres to just about any surface and shrinks very little. Ideal for moving joints--stretches up to 7 times its cured width.	Usually cannot be painted--some come in various colors.	High
Nitril Rubber	Long lasting--15 to 20 years. Extremely good for high moisture areas. Adheres well to metal, masonry and other unprimed surfaces. Can be painted after 10 to 20 minutes --painting is not necessary.	Shrinks considerably--do not use on moving joints or cracks over 1/8". Does not adhere well to painted materials.	High

TABLE VI. CHARACTERISTICS OF DIFFERENT TYPES OF CAULKING (CONTINUED)

Type of Caulk	Advantages/Application	Problems/Solutions	Cost
Neoprene Rubber	15 to 20 year life span. Especially good for use on concrete walls and foundations. Moderate shrinkage—can be used on moving joints less than 1/4 inch. Accepts paint but not needed.	Dries tack-free in about 1 hour but takes from 1 to 2 months to cure fully. Ordinary solvents are of no help in removing neoprene rubber—use either MEK or tolulene with caution.	High
Polysulfide	Over 20-year life on moving joints. Thoroughly shrink resistant.	CAUTION: Toxic until cured—up to 3 full days before tack-free. Special primer required on porous surfaces such as wood or masonry. Tolulene and MEK will clean away excess—follow directions on label.	High
Hypalon	Excellent caulk made to last up to 20 years. It can be used on moving joints. Will adhere to any surface. Easy to work with.	Not in general distribution. Requires priming before use on porous materials —check label.	High
Polyurethane	Can be used on moving joints. Will last up to 20 years. Will adhere to any surface, no priming needed. Easily applied.	Requires 24 hours to become tack-free and up to two weeks to cure. Not in many retail outlets. Use paint thinner or acetone for cleanup.	Low
Rope Caulk	Can be used on wide gaps. Does not dry out. Does not shrink. Easily applied—seasonal use is possible on storm windows.	Considered only a temporary solution to air leaks. Cannot be painted.	Low

Installing Weatherstripping and Caulking

If a new building is being constructed, select windows and doors for their energy efficiency as well as their appearance and price. If descriptive literature on doors and windows does not give information on the U-value of various glazing methods and the infiltration rate per unit length of crack area, ask your salesman or dealer to provide this information.

On completion of this section, you will be able to install weatherstripping and caulking properly.

There are two basic steps that can be taken to stop or slow infiltration into a building. They are discussed under the following headings:

1. Installing Weatherstripping.
2. Installing Caulking.

1. INSTALLING WEATHERSTRIPPING

Weatherstripping is installed primarily on doors and windows. There are many kinds of weatherstripping. Some of the most popular ones are shown in Figure 95. Weatherstripping is sold by the running foot, or in the case of some weatherstripping for doors, by the set. Those made of foams or plastic such as vinyl should be checked yearly, as the materials tend to lose their resiliency and become less effective. All weatherstrips should also be checked for signs of wear and breakage, and metal ones should be checked to make sure that they are not bent out of shape.

Installing weatherstripping is discussed under the following headings:

a. Weatherstripping Doors.
b. Weatherstripping Windows.

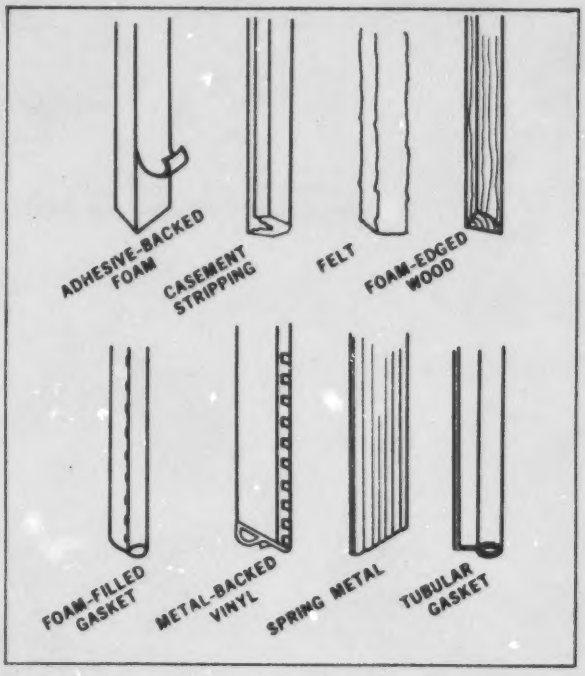

FIGURE 95. Types of weatherstripping.

a. Weatherstripping Doors

Garages are usually not heated, but homeowners like to keep them as warm as possible. Swinging doors may be treated the same as exterior doors in the rest of the house. Overhead doors should have a rubber astragals fastened to the bottom of the door with roofing nails spaced 2-3 inches apart. If the overhead door needs to be very airtight, weatherstripping may be nailed on the door stop so that it fits tightly against the exterior of the door.

(1) AROUND DOORS. The following procedure is used to install weatherstripping around a door:

1. Check door for air leakage.
2. Cut weatherstripping to proper length.

Use saw, hacksaw, or tin snips, whatever is appropriate for the given material.

3. Close door and install weatherstrip on latch side first.

   Press weatherstrip against door and fasten with nails, screws or staples.

4. Install on hinge side of door and then install piece over top of door.

5. Check door.

   If it closes too hard, weatherstrip may be pressed too tightly to door. If door closes easily, check with hair dryer for further air leakage.

(2) THRESHOLD. Because of the motion of the door, possible unevenness of the floor, and wear from traffic, the bottom of the door is usually more difficult to make airtight. If weatherstripping is attached to the door along the bottom, it should be adjusted periodically (Figure 96). One variety is attached to the door at the bottom on the outside and is made to swing down into place as the door closes, helping to eliminate drag on the weatherstripping.

An aluminum threshold with a vinyl insert is frequently used (Figure 97). The following procedure is used in installing one:

1. Shut door and use a scribe to mark a line on the inside of the door 1.6 cm (5/8 in) up from the surface upon which the threshold is to be mounted.

2. Pull the hinge pins on the door and cut the door off, following the line, and level it 3 mm (1/8 in) to the outside to slide over the threshold first and compress the vinyl insert as the door is closed.

FIGURE 96. Adjustable threshold.

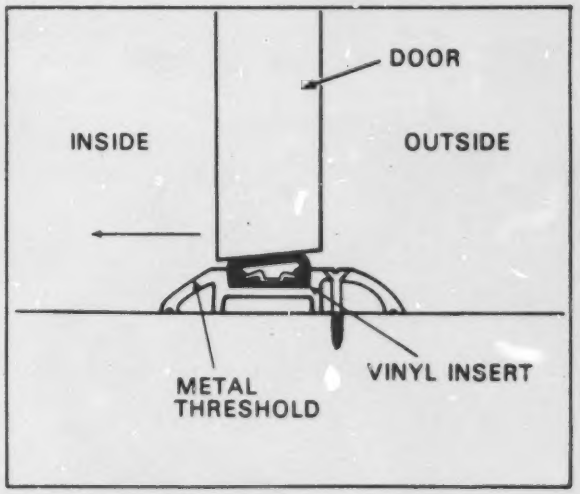

FIGURE 97. Aluminum threshold with compression seal.

3. Measure between the door and mark the threshold.

   Try to leave screw holes near the ends of the threshold if possible.

4. Use hacksaw to cut off threshold to length.

5. Install threshold with screws to floor.

6. Cut and install vinyl insert.

7. Check door for ease of closing and threshold for seal.

b. Weatherstripping Windows

Casement, awning, hopper, and fixed windows are easy to apply weatherstripping to because all weatherstripping can be applied from the same side. Casement and awning windows could have weatherstripping applied on the inside. Hopper and fixed windows would have it applied on the outside. Other openings that have removable covers such as attic access doors and disappearing stair units may also have to be weatherstripped.

For double-hung and sliding windows, proceed as follows:

1. Nail spring metal inserts into the sash channels and spring metal flashing to the bottom of the lower sash and inside edge of upper meeting rail (Figure 98).

2. Stick adhesive-backed foam to the bottom rail of the lower sash, the exterior of the meeting rail of the upper sash, and to the parting bead (Figure 99).

3. Vinyl weatherstripping may be nailed to the same surfaces. Apply it to the bottom rail of both the lower and upper sash (Figure 100).

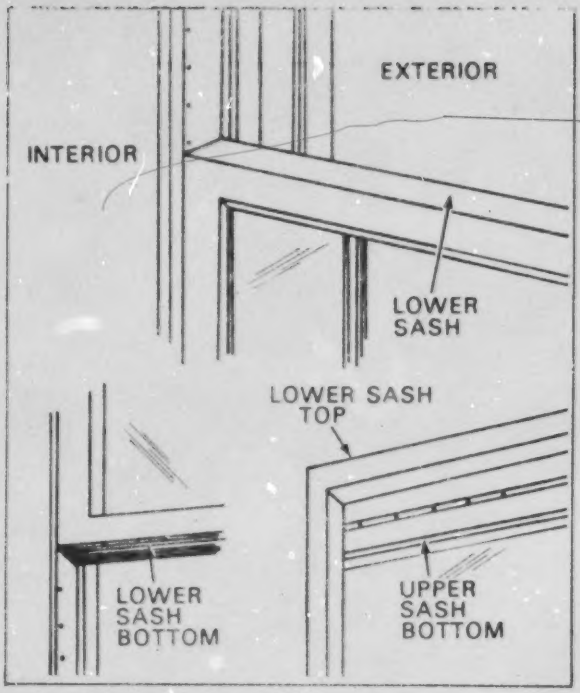

FIGURE 98. Spring metal inserts for double-hung windows.

FIGURE 99. Adhesive-backed foam applied to bottom of window sash.

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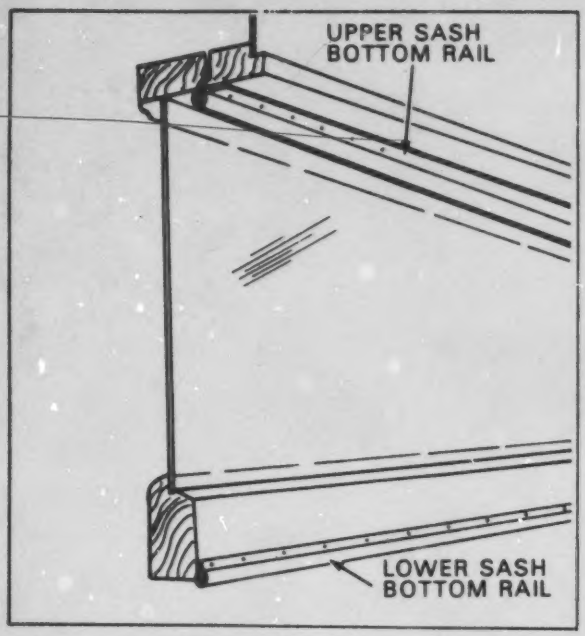

FIGURE 10C. Vinyl weatherstripping.

2. INSTALLING CAULKING

Caulking can protect against infiltration and retard heat loss through cracks in the house as well as protect the structure from insects and moisture.

Any time there is a crack between two different parts of a house, it should be caulked. Figure 101 shows some of the places where a house should be caulked.

The following steps should be carried out when applying caulking:

1. Use a wire brush, scraper, or chisel to clean out old caulking.
2. Large cracks may have to be packed with oakum.
3. Use solvent to clean area.

   Also be sure that area is not wet.
4. Cut tip off nozzle of caulking tube at 45-degree angle.

   The farther up the tip that the cut is made, the larger the bead of caulking will be. Caulking should lap both sides of the crack.
5. Insert rear of tube into gun first and drop nozzle into slot in front of gun.

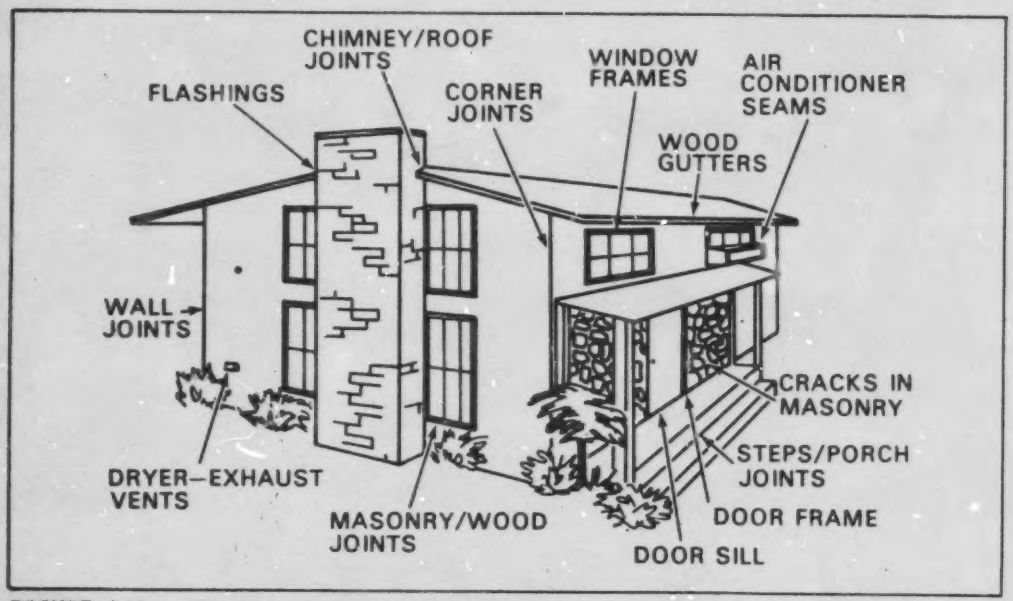

FIGURE 101. Places where caulking may be needed.

6. Push a sharp object into the nozzle to break the plastic seal at the base of the cartridge.

7. Hold caulking gun at a 45-degree angle to the surface to be caulked (Figure 102).

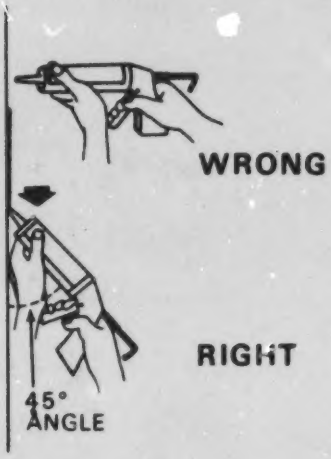

FIGURE 102. Proper use of caulking gun.

8. Squeeze trigger of caulking gun with slow, even pressure until caulking begins to come out of end of nozzle.

9. Move nozzle slowly and steadily along the crack, allowing the tip to form the bead of caulking.

   Do not let the tip of the nozzle smear the caulking. Your goal is an even and neat-looking job. Move the gun from top to bottom, and for right-handed people, from left to right.

   It will take practice to get proficient with a caulking gun but do not get discouraged. The best bead is made in one steady, continuous pass. Start in an inconspicuous place and do not be afraid to clean up a few of the first tries and start again.

10. When a crack is finished, remove the gun and release the pressure on the caulking tube by twisting the plunger rod to disengage it from the trigger ratchet.

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TABLE V. CHARACTERISTICS OF DIFFERENT TYPES OF WEATHERSTRIPPING

Type of Weatherstripping	Material/Form	Advantages	Problems	Cost
Pressure-Sensitive, Adhesive-Backed Foam	Polyurethane foam with vinyl cover in roll OR closed-cell vinyl foam.	Easy to install. Cushioning effect--noise reduction in closing. Good seal.	Avoid painting--causes loss of resiliency. 1-3 yr life--not durable. More effective on doors.	Low to medium.
Metal Spring Self-Sticking	Bronze, copper, stainless steel, or aluminum. V-shaped or single roll strip.	Excellent seal. Very durable. Easy to install.	Requires patience for installation.	Medium.
Felt or Self-Sticking	Variety of widths and thicknesses in a roll.	Easy to install. Various colors.	Variable life--may stick to door finishes.	Low.
Serrated Metal	Felt or vinyl-backed metal roll.	Easy to install.		Medium.
Tubular Gasket (rolled vinyl) Foam-Filled Tubular Gasket	Flexible vinyl in tubular form with or without metal backing.	White or gray. Easy to install. Very good, durable seal.	Cannot be painted or it will lose flexibility. Extra strength, holds shape. Extra insulating value.	High.
Interlocking Metal	Two interlocking pieces--strip.	Tight seal. Best available for doors.	Difficult to install due to alignment and cutting. Maintenance requires straightening of bent pieces.	High.
Casement Window Gasket	Vinyl roll.	Easy to install--slip on lip of window.	Gray only.	Medium.

TABLE V. CHARACTERISTICS OF DIFFERENT TYPES OF WEATHERSTRIPPING (CONTINUED)

Type of Weatherstripping	Material/Form	Advantages	Problems	Cost
Jalousie Gaskets	Clear vinyl. U-shaped track.	Easy to install-slip on.		Medium.
Door Sweeps	Wood and felt or wood and foam or metal and vinyl strips.	Easy to install. Effective seal against drafts.	Must clear carpet.	Medium.
Thresholds	Vinyl insert in metal base strip OR two-piece interlocking strip.	Generally best seal for exterior doors.	Often requires removal of old threshold or cutting of door.	High.

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TABLE VI. CHARACTERISTICS OF DIFFERENT TYPES OF CAULKING

Type of Caulk	Advantages/Application	Problems/Solutions	Cost
Oil Base	Adheres to most surfaces--prime porous surfaces.	Not for use on moving joints. As oil dries out, caulk shrinks; 1 to 7 year life--prolong life by painting after drying.	Low
Latex Base	Long life up to 10 years (some are guaranteed for 20 years). Adheres well to most surfaces--prime or paint metal and porous surfaces. Dries quickly. Can be painted in 15-30 minutes--accepts most paints.	Shrinks some--apply a big bead of caulk and use it to fill only narrow cracks.	Medium
Butyl Rubber	Should last up to 10 years if properly applied. Can be applied indoors or out, on metal or masonry. Can be painted with any type of paint after curing for a week.	Shrinks a little--apply a wide bead and cover only small cracks.	Medium
Polyvinyl Acetate (PVA)		Loses flexibility when it dries--use only for small holes indoors.	High
Silicone Seal	Excellent sealant--can last for at least 20 years. Adheres to just about any surface and shrinks very little. Ideal for moving joints--stretches up to 7 times its cured width.	Usually cannot be painted--some come in various colors.	High
Nitril Rubber	Long lasting--15 to 20 years. Extremely good for high moisture areas. Adheres well to metal, masonry and other unprimed surfaces. Can be painted after 10 to 20 minutes --painting is not necessary.	Shrinks considerably--do not use on moving joints or cracks over 1/8". Does not adhere well to painted materials.	High

TABLE VI. CHARACTERISTICS OF DIFFERENT TYPES OF CAULKING (CONTINUED)

Type of Caulk	Advantages/Application	Problems/Solutions	Cost
Neoprene Rubber	15 to 20 year life span. Especially good for use on concrete walls and foundations. Moderate shrinkage—can be used on moving joints less than 1/4 inch. Accepts paint but not needed.	Dries tack-free in about 1 hour but takes from 1 to 2 months to cure fully. Ordinary solvents are of no help in removing neoprene rubber—use either MEK or tolulene with caution.	High
Polysulfide	Over 20-year life on moving joints. Thoroughly shrink resistant.	CAUTION: Toxic until cured—up to 3 full days before tack-free. Special primer required on porous surfaces such as wood or masonry. Tolulene and MEK will clean away excess—follow directions on label.	High
Hypalon	Excellent caulk made to last up to 20 years. It can be used on moving joints. Will adhere to any surface. Easy to work with.	Not in general distribution. Requires priming before use on porous materials —check label.	High
Polyurethane	Can be used on moving joints. Will last up to 20 years. Will adhere to any surface, no priming needed. Easily applied.	Requires 24 hours to become tack-free and up to two weeks to cure. Not in many retail outlets. Use paint thinner or acetone for cleanup.	Low
Rope Caulk	Can be used on wide gaps. Does not dry out. Does not shrink. Easily applied—seasonal use is possible on storm windows.	Considered only a temporary solution to air leaks. Cannot be painted.	Low

STUDY GUIDE IV-3-1

Circle letter(s) that represent the correct answer(s), unless instructed otherwise.

1. Three advantages of caulking and weatherstripping are to:

   a. Increase the U-value of walls.
   b. Reduce the air exchange.
   c. Keep out insects.
   d. Reduce energy use.
   e. All of the above.

2. Weatherstripping is used on:

   a. Doors and windows that open and close.
   b. Cracks around window frames.
   c. Soffit vents.

3. Types of weatherstripping are:

   a. Pressure sensitive foam.
   b. Metal spring.
   c. Felt.
   d. Flexible plastic.
   e. All of the above.

4. Weatherstripping and caulking are:

   a. Easy to install.
   b. Difficult to install.

5. All caulking is the same.

   a. True.
   b. False.

6. Types of caulking most desirable are:

   a. Latex base.
   b. Butyl hose.
   c. Neoprene rubber.
   d. All of the above.

7. Weatherstripping and caulking should be done:

   a. As a last resort.
   b. Frequently.

STUDY GUIDE IV-3-2

Circle letter representing correct answer, unless instructed otherwise.

1. The purpose of weatherstripping and caulking is to reduce _____.

2. Weatherstripping is used primarily on _____ and _____.

3. Adjustable thresholds are available to reduce infiltration under doors.

   a. True.
   b. False.

4. Weatherstripping procedures vary with the type of window.

   a. True.
   b. False.

5. Types of weatherstripping are as follows:

   a. Adhesive-backed foam.
   b. Felt strips.
   c. Foam-edged wood.
   d. Spring metal.
   e. All of the above.

6. Caulking is used to stop cracks in outside walls whenever they occur.

   a. True.
   b. False.

7. Weatherstripping may be:

   a. Self-adhesive.
   b. Tacked on.
   c. Either.

8. Caulking gun should be held at:

   a. 20 degree angle.
   b. 45 degree angle.
   c. 90 degree angle.

9. Move caulking gun away from the direction in which it is pointed.

   a. True.
   b. False.

Unit IV
Answer Key IV-3-1

1. b c d
2. a
3. e
4. a
5. b
6. d
7. b

Answer Key IV-3-2

1 air infilitration
2. windows and doors
3. a
4. a
5. e
6. a
7. c
8. b
9. a

Unit IV

FLOORS, WALLS AND CEILINGS

COMPETENCY 4: Select Energy Efficient Insulation

LEARNING STEPS:

1. Define the various types of insulations available for use in floors, walls and ceilings.
2. Determine the R value of the various insulation materials.
3. Determine the type and amount of insulation necessary for a given R value.
4. Select the appropriate type and amount of insulation.

LEARNING ACTIVITIES

1. Attend a teacher lecture on insulation in new and existing structures for walls and ceiligs.
2. Read Information Sheet IV-4-1 "What Type and How Much Insulation to Use."
3. Define the types of insulation.
4. Visit local suppliers and report on the types, availability, and costs of insulation.
5. Attend a lecture/demonstration on the selection of insulation given by a representative of a insulation manufacturer.
6. Answer the questions on Study Guide IV-4-1.
7. Read Information Sheet IV-4-2 "Installing Insulation in the structure."
8. Answer the questions on Study Guides IV-4-2, IV-4-3 and IV-4-4.

What Type and How Much Insulation to Use

Insulation is one of the most important considerations when constructing or renovating a building. The amount of insulation you use and where it is placed affects not only your winter and summer fuel and electric bills, but your comfort as well.

The function of insulation is to slow the transfer of heat from the warm side of a wall, ceiling or floor to the cold side. As you already know, some materials resist the flow of heat better than others. Thermal conductance (U) or rate of heat transfer can be measured. Those materials which resist the flow of heat are called insulators. Insulation materials are rated by R-values (resistance to energy flow).

Insulation for buildings is made so that air is trapped in many small pockets in the materials. The tiny fibers in fiberglass, for instance, create thousands of small "dead air spaces" in the material. Also, when plastic foam is applied as insulation, thousands of tiny closed cells filled with nonconductive gases are formed. The movement of heat through these materials is slow because the trapped air spaces or closed cells are so small that the heat cannot easily move from the warm side to the cold side by convection.

Insulators are usually compared to each other by using the term resistance. The higher the resistance or R-Value of a material, the better it insulates. The R-value of a material is specified for a certain thickness of that material. Adding the R-values for each element of a wall, for instance, will give us the total resistance to heat flow for that part of the building. The higher the total resistance the better that part of a building will be in saving energy both winter and summer.

Both the builder and the homeowner have basically the same materials to choose from when selecting insulation. However, some materials should be installed by professionals. From this section, you will be able to list factors to consider in the selection of building insulation. They are discussed under the following headings:

1. Types of Insulation.
2. Effect of Climate and Geographic Location.
3. Effect of Construction Methods.
4. Effect of Insulation Quality.
5. Effect on Energy Use.
6. Effect on Cost Benefits.

1. TYPES OF INSULATION

Insulation comes in various forms and is made from several materials. In addition to considering its insulating quality, we must know if it is fire resistant, and vermin and insect proof. Table II compares several insulation materials.

There are several features that are important when considering the insulators that are commercially available; cost, resistance factor per inch of thickness, fire rating and durability. Let us first look at the forms of insulation that are available:

Blankets. Blankets come in rolls, usually from 41 to 61 cm (16 to 24 in) wide, and are unwound and cut to fit in place between wall studs or ceiling and floor joists.

Batts. Batts are similar in size to blankets but are precut to specified lengths.

Boards. Boards are precut to standard sizes and are usually applied with a mastic as perimeter insulation around the foundation or over existing walls for renovation work.

Loose-fill. This type of insulation comes as a loose granular material in bags and can be poured or blown into place between joists or behind walls.

Blown Insulation. This is a pneumatically blown type of insulation which is installed under pressure behind walls and between joists in ceilings and floors by professionals.

Now, let's look at the qualities that the various commercial insulators have. They are discussed as follows:

a. Loose-Granule, Mineral-Based

The most common of these are vermiculite and perlite, available as loose-fill insulation at moderate cost (Figure 20). The resistance is about SI 0.44 (US 2.5) per inch of thickness. These materials are fireproof and will not deteriorate from moisture, rot or insect problems. However, settling can be a problem, particularly when they are placed in a vertical position between wall studs.

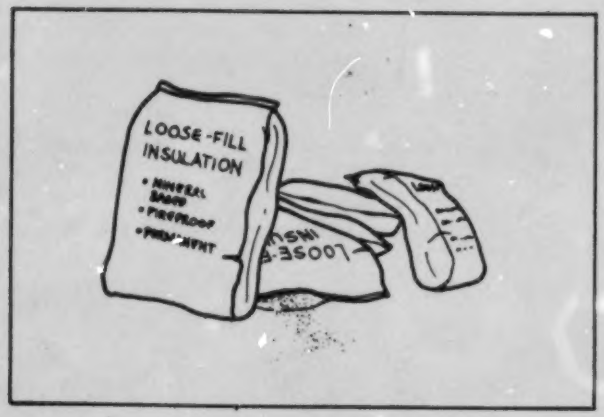

FIGURE 20. Loose-granule, mineral-based insulation is fireproof and will not deteriorate.

b. Fiberglass

Fiberglass is perhaps the most common of all insulators today; it is available in rolls, batts and loose-fill (Figure 21). The resistance of fiberglass is SI .41 to .62 (US 2.6 to 3.5) per inch of thickness. It is fire and vermin proof, moderate in cost and easy to install. The result is that the material is compressed a bit and loses some of its insulation value. It is a skin irritant when handled.

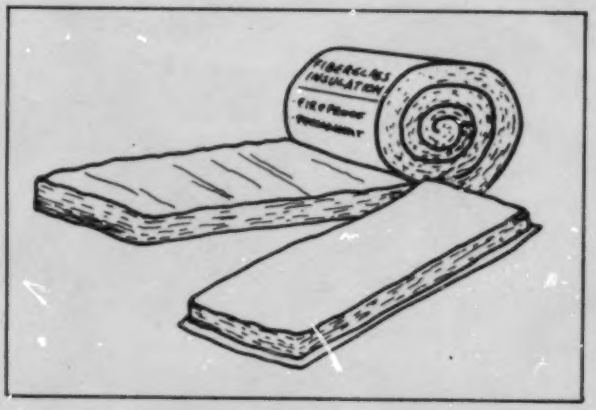

FIGURE 21. Fiberglass insulation cover is fireproof and will not deteriorate.

c. Mineral Fiber

Rock or mineral fiber is much like fiberglass except that the material is made from melted rock and slag instead of glass (Figure 22). Its cost and R-Value are nearly the same as fiberglass. Like fiberglass, mineral fiber can irritate the skin when handled.

FIGURE 22. Rock wool is fireproof and permanent.

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d. Insulation Sheathing

This is a material commonly made from wood fibers and is usually applied on exterior walls as a backing for siding (Figure 23). It comes in various thicknesses, usually between 1.3 and 2.5 cm (1/2 and 1 in). The resistance is about 2 per inch of thickness, and though it is water repellent, extended exposure to moisture will cause damage through mildew and rot. It is not fire resistant.

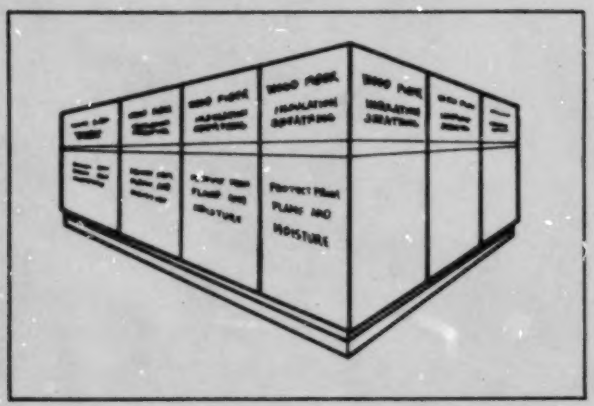

FIGURE 23. Insulation sheathing is made from wood fibers and is subject to rot if exposed to moisture.

e. Cellulose Fiber

These fibers are often made from recycled paper and when properly treated—are fire resistant (Figure 24). It does not irritate the skin. In its loose-fill version, cellulose has a fine consistency, permitting blow-in installation through small access holes. Just make sure that the label carries the brand name and treatment certification of a reputable manufacturer.

f. Plastic Insulation

The most common type of plastic insulation is polystyrene which comes either as a blue "closed-cell" form board or as white granule boards with the granules heated and pressure treated so they adhere together (Figure 25). The resistance per inch is about SI 0.97 (5.5) for the blue and SI 0.71 (US 4.0) for the white. Polyurethane, on the

FIGURE 24. Cellulose fiber is supposed to be treated by the manufacturer for fire and vermin resistance.

other hand, comes as a closed-cell foam board. In either case, its resistance value is about SI 1.14 (US 6.5) per inch. Polystyrene and polyurethane tend to be expensive. Although both are good insulators and do not attract moisture or vermin, there are extreme fire hazards involved. Both will burn very rapidly and give off toxic gases; therefore, they should never be installed where they will be exposed. They can be covered with wallboard, exterior siding, or other material as specified by local codes. Since it is moisture resistant, it can be used below grade. It is often used around foundations and crawl spaces and has been used as a base for providing extra insulation under a poured concrete slab.

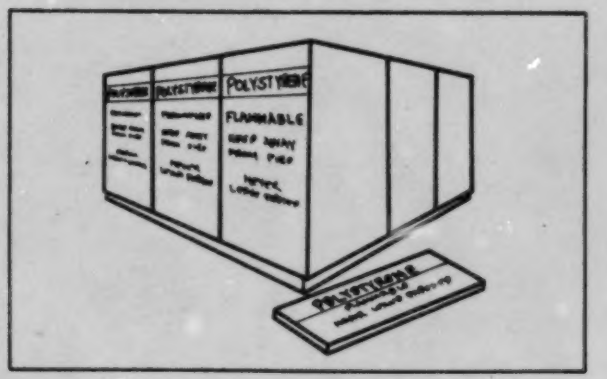

FIGURE 25. Polystyrene insulation is good insulation but it should always be covered by other building materials.

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g. Urea-Formaldehyde

This is a moderately priced, foamed-in-place insulation. It is chemically stable, non-toxic, and will not attract moisture or insects. It is fire resistant. This material shrinks between 1.8% and 3.0% when it sets, creating small spaces between the studs. If the rest of the wall is tight, the shrinkage does not present a problem. The resistance of this material is about SI 0.71 (US 4.0) per inch of thickness. It requires a competent installer to insure good results (Figure 26).

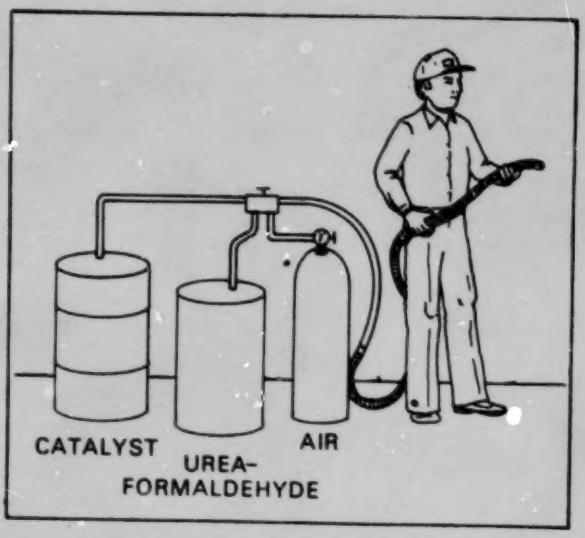

FIGURE 26. Urea-formaldehyde is fire resistant and will not attract moisture or insects.

NOTE: There has been some problem with improper installation with this material. Be sure and check out the success of your manufacturer before using this material. If you do use it, follow directions specifically.

2. EFFECT OF CLIMATE AND GEOGRAPHIC LOCATION

Although seasonal temperature variations are common to all climatic regions of the United States, each area generally has more seasonal cold or warm weather than another. Temperature is accompanied by moisture variations, wind and other elements.

Your choice of the type and amount of insulation to use depends on climate, energy costs, insulation costs, and other factors such as building features.

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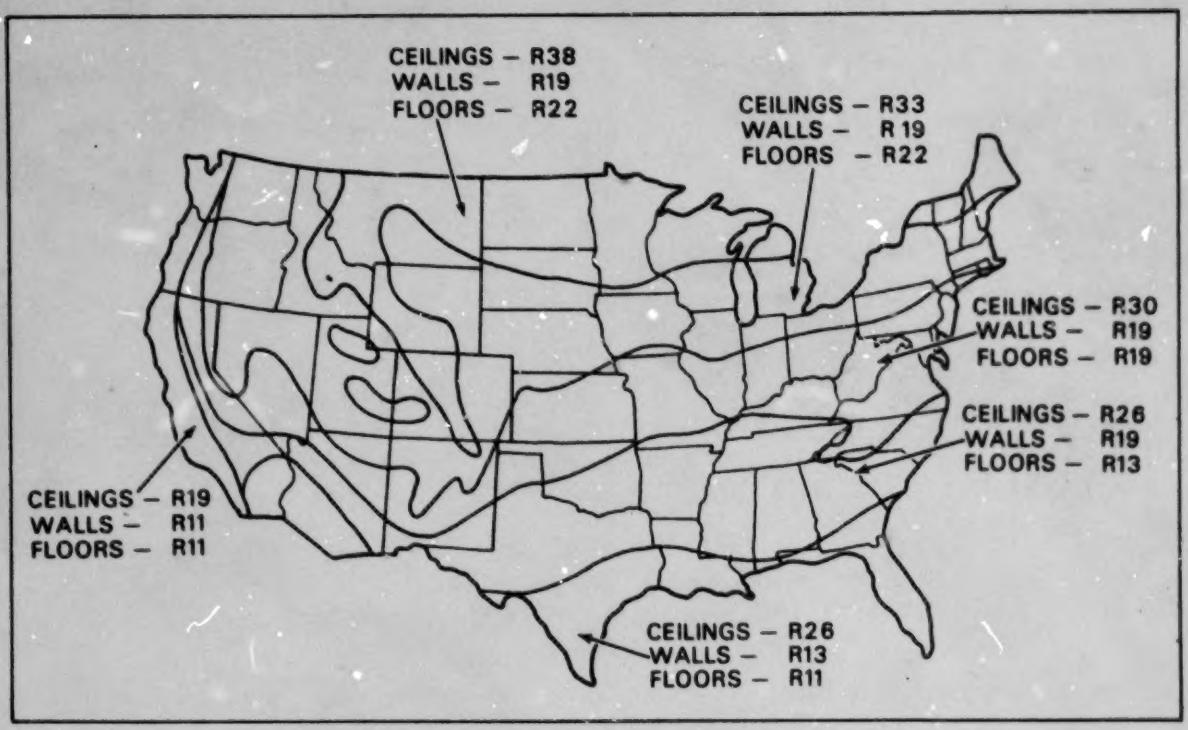

FIGURE 27. This map shows minimum insulation recommendations for ceilings/walls/floors in six (6) different insulating zones of the United States. The "R-Value" guidelines are for the economical amounts of insulation to have, considering climate, energy costs, insulation price, and other factors (Owens-Corning).

Many insulation recommendations have been made by housing agencies, contractors, and insulation manufacturers. The map in Figure 27 shows minimum insulation recommendations (R-Value) for six insulating zones of the United States.

More specific information can be had by finding the number of degree days for your area and referring to Table IV, or make a survey of your building.

3. EFFECT OF CONSTRUCTION METHODS

You know that heating and cooling requirements vary from one region of the United States to the other. And, even though building materials are quite similar throughout the country, construction methods do vary from one climate to another. In the case of insulation, the temperature variation in a given region or location is the basic reason for the construction method used. We need to realize that an ordinary wall without insulation is seldom sufficient to provide comfort in either warm or cold climates. Walls, ceilings, and floors seldom provide enough resistance to heat transfer without some form of insulation. Therefore, the selection of insulation provides the opportunity to make a building energy-saving and comfortable.

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INFORMATION SHEET IV-4-2

Installing Insulation in the Structure

Before installing insulation in new construction or remodeling work, all carpentry required to frame the structure, as well as all electrical, plumbing, and heating-cooling rough-in procedures must be completed, to allow only a minimum of disturbance to the insulating material after it has been installed.

Insulation should be installed on all surfaces where the flow of heat will be detrimental to the efficient heating and/or cooling of a building. The methods of installing insulation differ somewhat depending upon the part of the structure to be insulated. From your study of this section, you will be able to install insulation properly. Procedures are given under the following headings:

1. Installing Insulation in the Ceiling.
2. Installing Insulation in the Floor.
3. Installing Insulation in the Walls.
4. Installing Insulation in the Basement and Crawl Space.

1. INSTALLING INSULATION IN THE CEILING

Only those ceilings exposed to unheated attics or directly covered by roofs need to be insulated. However, because the heat loss is greatest through ceilings and proper ventilation of attics is essential, it is very important that insulating is done properly. Figure 66 shows where insulation should be placed

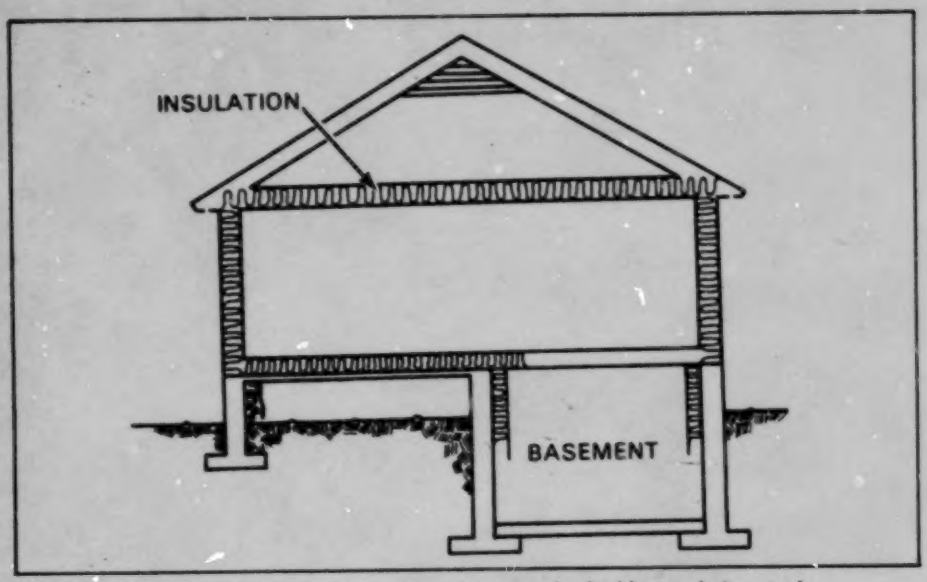

FIGURE 66. Insulation for a one story building with attic.

in a one story house with an attic. If the house has access to the attic by way of a stairway, Figure 67 shows how the stairwell should be insulated. Buildings which have no attic, as in Figure 68, must have insulation in the roof-ceiling area, making certain to allow enough space above the insulation for air circulation. Figure 69 shows where insulation must be placed in houses

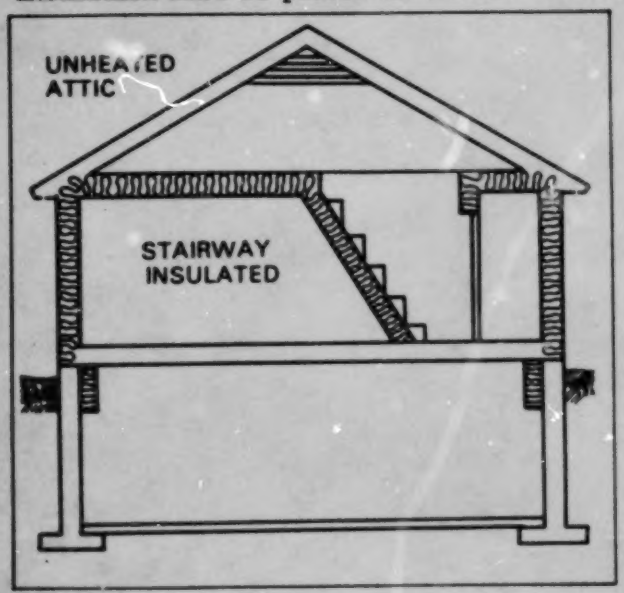

FIGURE 67. Stairway to unheated attic should be insulated.

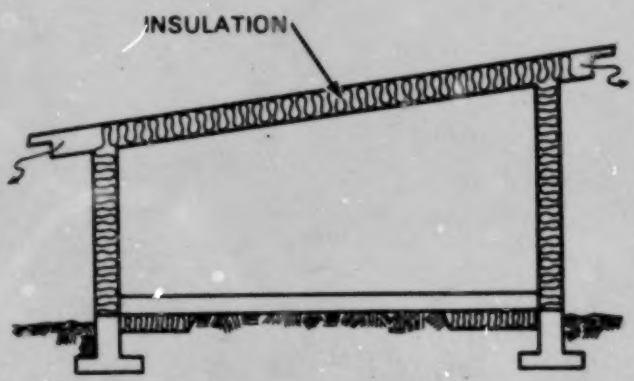

FIGURE 68. Building with no attic space must have insulation under the roof.

where some of the attic area has been finished for living purposes, or dormers have been added for more living space, light, and ventilation. Again, it is important that a space be left between the insulation in the drop ceiling and the roof boards to allow air circulation from the attic area behind the knee wall to the upper attic area for proper ventilation.

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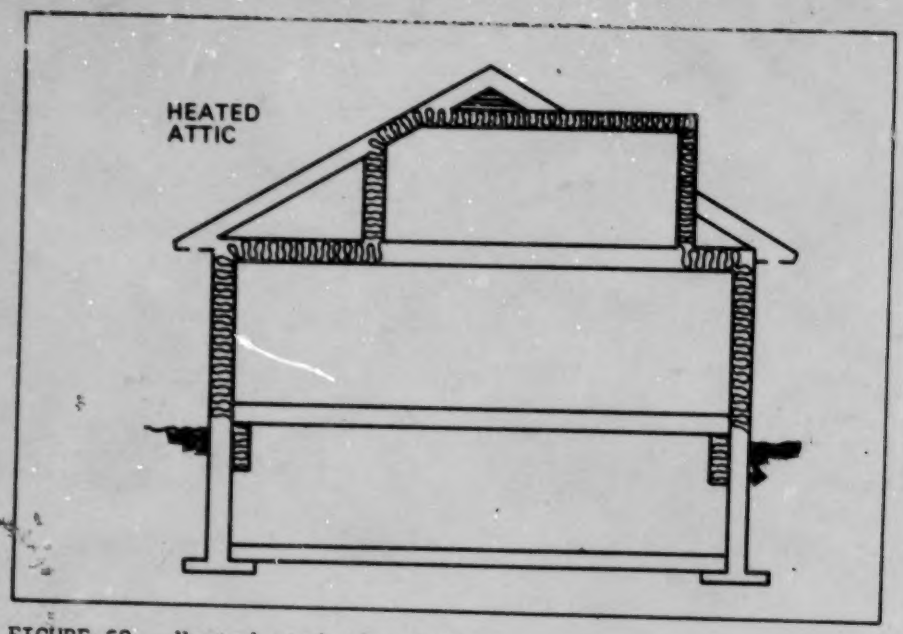

FIGURE 69. Heated attic insulation.

Insulation in ceilings of the following categories of insulation are described:

a. Flexible Insulation.
b. Loose-Fill Insulation.
c. Rigid Insulation.
d. Reflective Insulation.

a. Flexible Insulation

The majority of flexible insulation is manufactured with kraft paper or asphaltic, plastic, or aluminum vapor barriers adhered to at least one side. If the insulation has a vapor barrier, it is very important that the vapor barrier be placed toward the heated side of the ceiling (facing downward). It is also essential that the vapor barrier not be torn, as it then becomes less effective.

Batt or blanket insulation with a paper or vapor barrier backing is usually fastened to ceiling joists or studs in one of two ways. It is simplest to staple the flanges of the insulation to the edge of the stud or joist (Figure 70). This procedure makes for the best seal for the vapor barrier, but it sometimes leaves an uneven surface upon

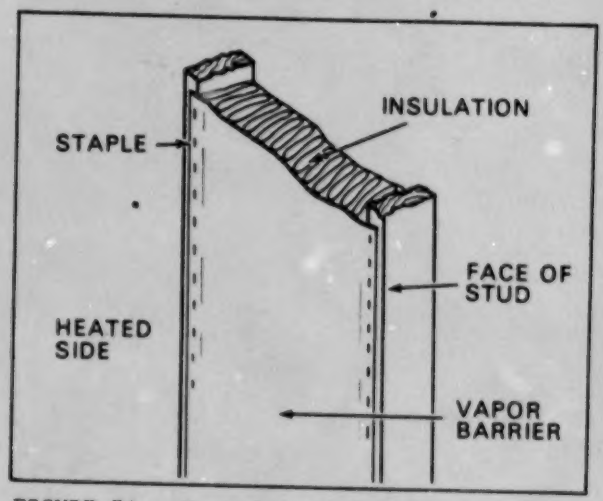

FIGURE 70. Most insulation is stapled to the face of the stud. Vapor barrier to the heated side.

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which to place wall covering and does not allow for the use of adhesives to hold wall coverings in place. Otherwise, the flange can be stapled along the side of the stud to form an air space between the insulation and the wall covering (Figure 71). The latter is the procedure required if the insulation has a reflective foil surface on it.

Blanket insulation comes in rolls and is usually available in thicknesses up to 3 1/2 inches. The thicker the insulation, the less area a roll will cover. Batts are available in thicknesses up to 6 inches and come in a series of shorter pieces packaged together. Both are made in widths for installation in 16-inch or 24-inch on-center spacing of framing members.

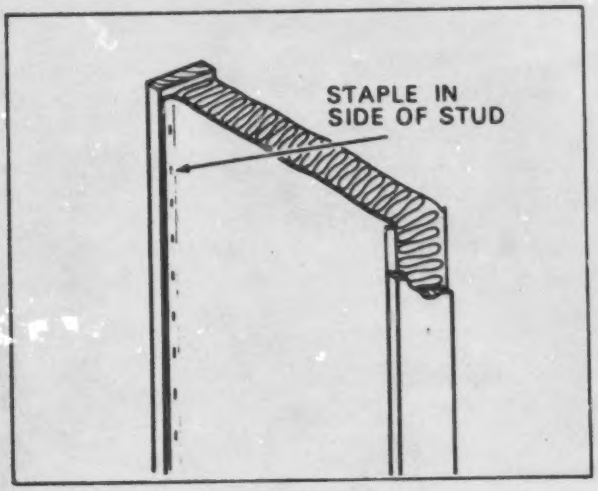

FIGURE 71. Some insulation is stapled to the inside of the stud to provide for certain wall coverings. If you have insulation with a reflective foil backing, it is required.

Batts or blankets may also be purchased without any backer or vapor barrier. These are made to fit in spaces between joists or studs by friction. Many spaces will require several batts to cover their length. Care should be taken that joints between batts are pushed tightly together. In ceilings, especially with 61 cm (24 in) o.c. framing, these are most successfully installed by laying them in after the ceiling covering has been installed. The measuring and cutting of such insulation is accomplished in the manner previously described. A separate vapor barrier will be needed.

If flexible insulation is to be used to add thickness to existing batt or blanket insulation, it is best to use the type that has no vapor barrier. If batt or blanket insulation with a vapor barrier is used, the vapor barrier should be slashed and again placed to the warm side but not fastened. If the space between ceiling joists is not filled with the first layer, the second layer is merely laid between the joists on top of the first. If the space has already been filled, the batts or blankets can be run at right angles to the direction in which the joists run, to give total coverage.

For protection, the installer should wear safety goggles and clothes that fit tightly about the neck and wrists.

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To install blanket insulation, proceed as follows:

1. Measure the length of the space to be insulated.

2. Add to this length another 10.2 cm (4 in) or 15.2 cm (6 in) if one end is to start at outside wall.

3. If several pieces of the same length are needed, measure this distance from a wall and make a mark on the floor (Figure 72).

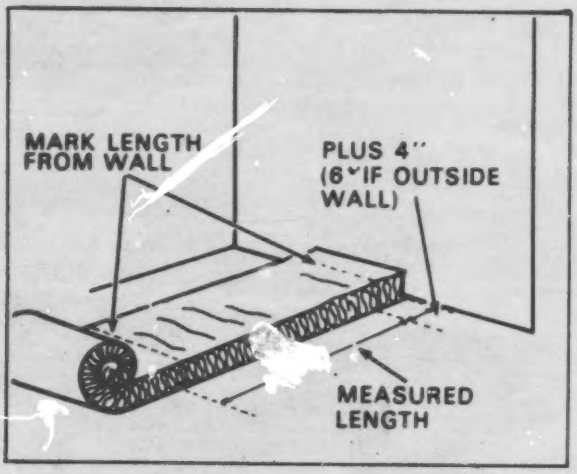

FIGURE 72. Cut sections to proper length.

4. Place end of blanket against wall and unroll to mark.

5. Compress the material with a straight edge and cut with a sharp knife (Figure 73).

6. Peel the insulation away from the paper or vapor barrier for about 5.1 cm (2 in) at each end—10.2 cm (4 in) if end is to start at outside wall (Figure 74).

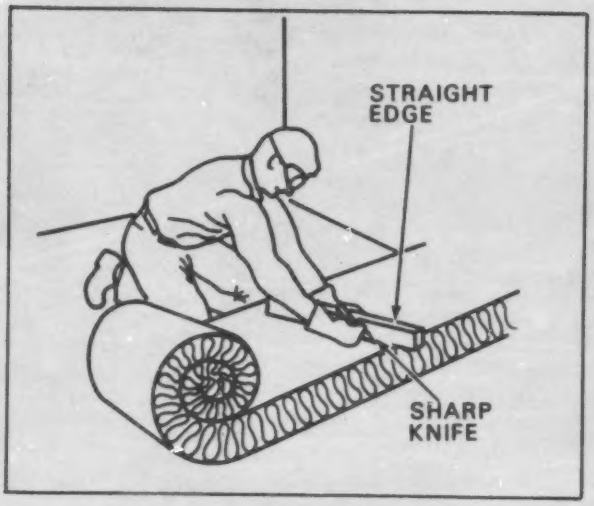

FIGURE 73. Compress the insulation with a straight edge and cut with a sharp knife.

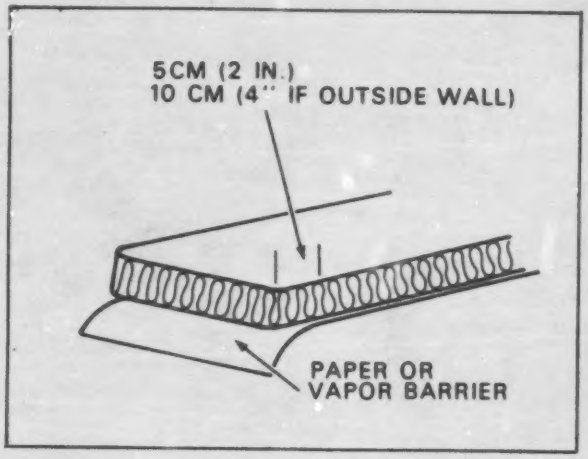

FIGURE 74. Peel insulation away from vapor barrier on end.

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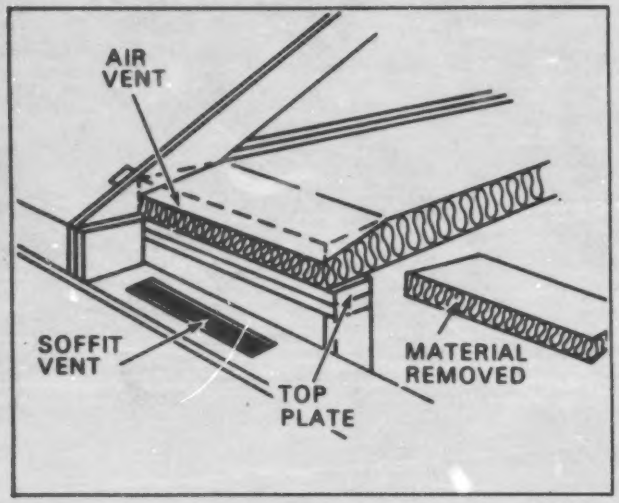

FIGURE 75. Provide air space for attic ventilation.

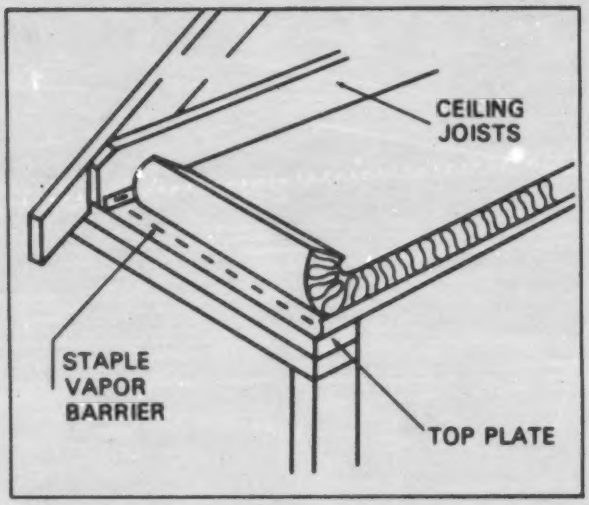

FIGURE 76. Staple vapor barrier or paper.

7. If one end is to start at outside wall and end of insulation over wall plate will block space between rafters to the underside of the roof boards, remove enough insulation from the top cover of the blanket to allow for at least 2.5 cm (1 in) of clearance for ventilation from cornice (Figure 75).

8. Place end of insulation on top of double top plate and staple paper or vapor barrier to edge of double top plate (Figure 76).

9. Staple to edge or side of ceiling joist or truss chord. Staples 6 mm (1/4 in) long should be no more than 15.2 cm (6 in) apart and care must be taken to have vapor barrier fit tight to joist (Figure 76).

10. Where there are electrical boxes in the ceiling, place the insulation above them and cut the insulation so that it can be fitted around the wires or conduit.

CAUTION! Do not place insulation within 7.6 cm (3 inches) of recessed fixtures. They are designed to dissipate the heat generated by the light bulbs into the air above them; covering them with insulation can cause them to overheat and possibly cause a fire to start. Also, do not cover non-ducted exhaust vents.

11. Use longer lengths first and the shorter pieces to do the shorter areas.

    If joints are made in an area, be sure to butt the ends of the pieces of insulation tightly together.

b. Loose-Fill Insulation

A very popular type of insulation to use in ceilings is loose-fill insulation. Some of these insulations, such as mica pellets, are easily placed by pouring and leveling while others such as glass or rock wool and cellulose fiber are best installed with a blower.

Certain preparations may be made so that the installation will be done most effectively. One of these preparations is the installing of cardboard baffles where the joist space meets the outside wall (Figure 77). The purpose of the baffles is to keep the insulation from being shoved or blown into the soffit area and to keep the insulation from blocking the flow of air from the soffit vents to the attic. The cardboard baffles may be purchased pre-cut and creased for bending, or they can be made of surplus cardboard by the installer. The baffles may be stapled or nailed into place with large headed nails. They are much easier to install in new construction before the roof boards have been put in.

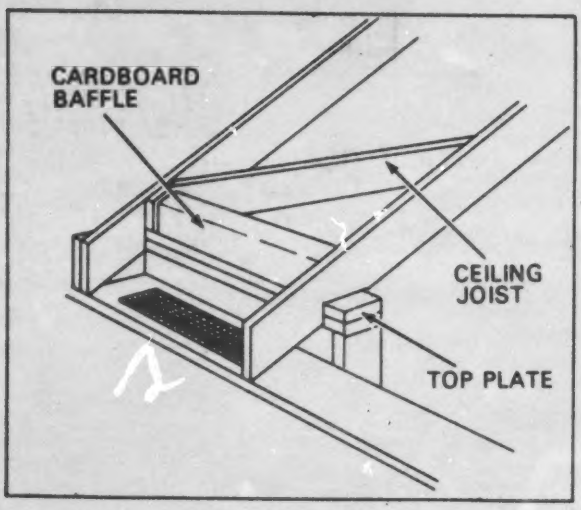

FIGURE 77. Place a baffle over plate to provide for attic ventilation.

If a vapor barrier is desired in the ceiling, it must be installed at this time. Installation of vapor barriers will be discussed in Part B.

Anyone who works with loose-fill insulation in closed spaces should wear a respirator in addition to safety goggles and clothing that fits tightly at the neck and wrists.

Loose-fill insulation may be installed by (1) pouring or (2) blowing. Either method may be used equally as well for installing additional insulation over existing insulation to increase the R-Value of the ceiling structure. Procedures are given as follows:

(1) POURING METHOD. If your insulation is the type that does not pack when bagged, following the pouring method:

1. Carry bags of insulation into attic.
2. Open bags and pour insulation in spaces between joists.
3. Level off insulation to desired thickness with leveling board (Figure 78).

   If depth desired is greater than joist, level by installing screeds perpendicular to the joists.

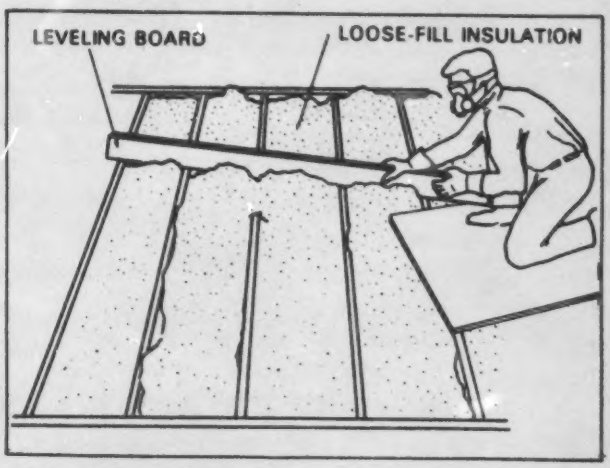

FIGURE 78. Level insulation with a board.

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4. Be sure that all areas are properly covered and that recessed lights are uncovered.

   To keep insulation from recessed fixtures or exhaust vents, use a non-combustible material such as sheetrock scraps to hold insulation back.

5. Remove empty bags from attic as they constitute a fire hazard.

(2) BLOWING METHOD. Glass and rock wools and cellulose fibers are best blown in place, because the process of blowing tends to restore the material to its natural fluffy state. This procedure enhances its insulating value. While a single individual can install insulation by the pouring method, it takes two people to blow in insulation. One person must feed insulation into the blower while the other directs the hose in the attic.

With the recent emphasis upon insulation, more insulation suppliers have blowers that they rent to individuals to enable them to do the insulating themselves. These blowers are usually equipped with an electric control which enables the person directing the hose to control the flow of insulation. A person who has not used a blower before should follow very closely the directions that are given when it is rented.

It is best to select an area easily accessible to make a trial application and complete coverage. Once this skill has been acquired, the most inaccessible spaces are filled first while the applicator works gradually toward the exit to the attic. The same precautions regarding recessed lights and unducted vents must be followed when insulation is blown in place.

c. Rigid Insulation

Rigid insulations are used primarily in ceilings where the roof and ceiling structure is one, such as plank and beam or bar joist and steel deck construction; therefore, it is usually installed when the building is constructed. Rigid cellulose fiber planks of 5.1 or 7.6 cm (2 or 3-inch) thickness may replace solid wood decking in plank and beam construction. It is laid on top of the beams and nailed in place with long spikes. Roofing is then applied over it. This method is more energy efficient than solid wood decking, but neither is adequate in view of the rising cost of energy. Therefore, it is now recommended that enough rigid insulation, probably one of the foam plastics, be placed over the decking to bring the R-Value up to the desired level (Figure 79). This method of insulation can be used to upgrade the R-Value of existing plank and beam ceilings as well.

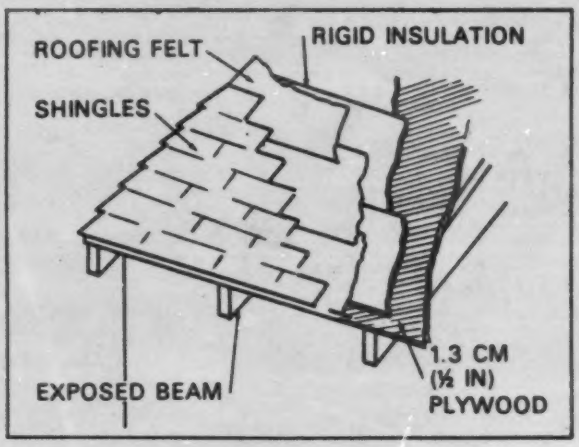

FIGURE 79. Rigid insulation placed over plywood ceiling with exposed beams.

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In sloped ceilings that are framed with rafters, the rafter is sometimes made deeper than necessary for structural strength, in order to accommodate the proper thickness of insulation and still provide an air space for ventilation. Lumber may be saved by sizing the rafters for strength and placing rigid insulation on the underside of the rafters in addition to the batts between the rafters. This method may also be used to upgrade the insulating value of existing structures (Figure 80).

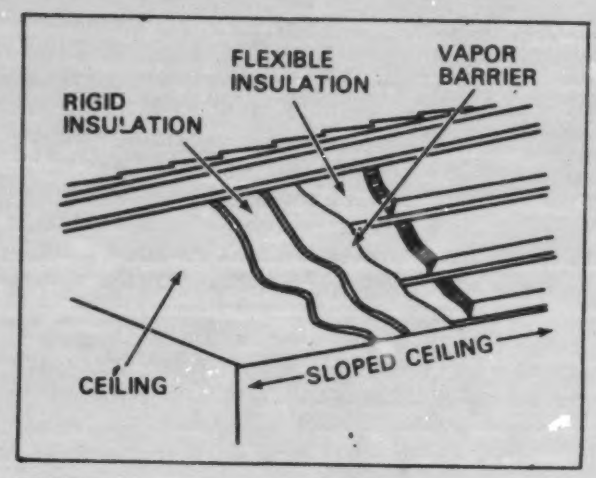

FIGURE 80. Use of both flexible and rigid insulation in sloping ceiling.

Some companies who manufacture materials for suspended ceilings are now trying to make the public aware of the insulating value of such ceilings. If information on the U-value of suspended ceilings is given, be sure to ascertain whether this refers to the U-Value of the panels or of the total suspended ceiling. The panels may be good insulators but the metal grid that supports the panels conducts heat readily. Such a ceiling installed for insulation purposes will be installed in a manner similar to any other suspended ceiling.

d. Reflective Insulation

Reflective insulations are seldom used in ceilings as the only form of insulation. They are most effective in climates where protection from summer heat is the major concern. The aluminum foil backing found on some batt and blanket insulations acts as a reflective insulation as well as a vapor barrier. In order to be effective, this insulation must be installed with an air space of at least 1.9 cm (3/4 in) between the reflective surface and any surface opposite it. The same holds true for reflective insulations made of a single sheet of material. Otherwise, the procedure followed in its installation is the same as for any other type of flexible insulation. Although stapling is the most popular method of fastening reflective insulation, it may also be nailed. It must, however, be fastened often enough to be held against the framing material without gaping.

Reflective insulations that unfold to form multiple air spaces, each surrounded with reflective surfaces, are provided with tabs for fastening them to the structure. Again, care must be exercised to keep the insulation at least 1.9 cm (3/4 in) away from the back side of the ceiling covering. This insulation is best installed in new constructions, or when remodeling rather than when used as a measure to upgrade the insulating value of an existing structure.

2. INSTALLING INSULATION IN THE FLOOR

Insulation in floors is installed only over unheated areas. Most insulation that is installed in floors has the heated area above it. Many times this insulation is not installed during the proper phase of construction or is installed later to make the floors warmer. These factors tend to make proper installation more difficult and lead to its being installed improperly.

Procedures vary for flexible, rigid and loose-fill insulation. They are given under the following headings:

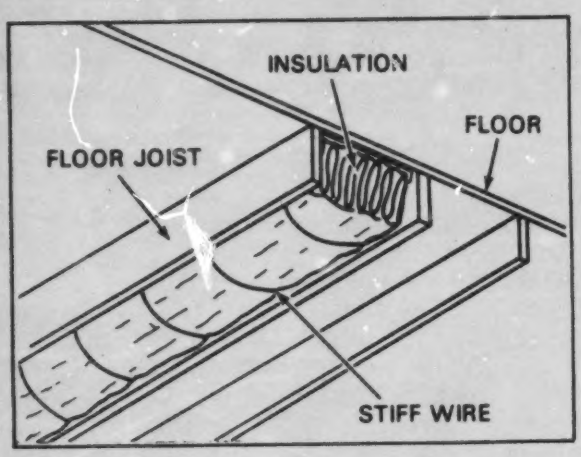

FIGURE 81. Stiff wire may be used to support flexible insulation between flow joists.

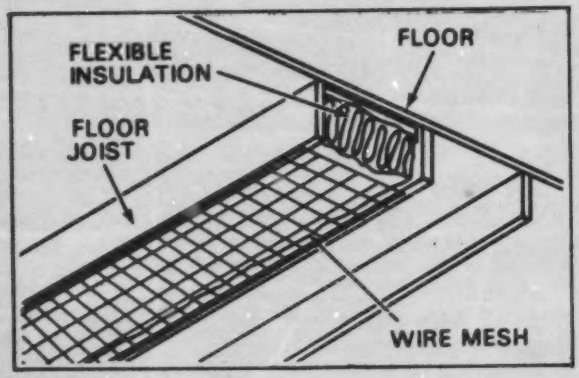

FIGURE 82. Mesh wire used to support insulation between floor joists.

a. Flexible Insulation.
b. Loose-Fill Insulation.
c. Rigid Insulation.
d. Reflective Insulation.

a. Flexible Insulation

Most flexible insulation has the vapor barrier on the side from which it is fastened, requiring that one of the following things be done.

The insulation should be installed from above by stapling it in place before the subfloor is put down.

Some insulation is made completely enclosed by kraft paper with the vapor barrier to be placed up and the stapling to be done from beneath.

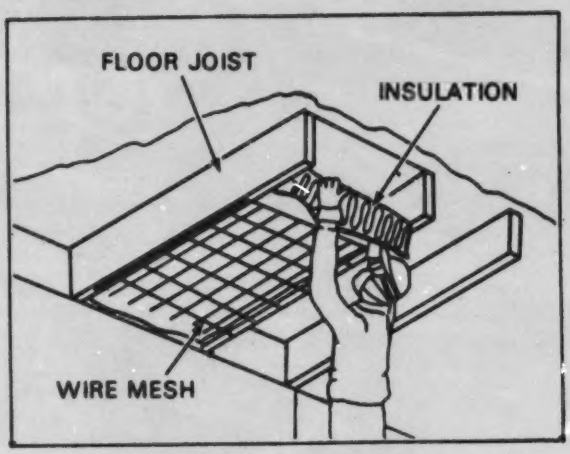

FIGURE 83. Installing flexible insulation under floor.

A vapor barrier can be installed above or beneath the subfloor and insulation without a vapor barrier can be installed from beneath. This is supported by wire. Use either pieces of heavy gage wire which are pointed on each end or wire mesh. Place the vapor barrier up (Figures 81 and 82).

(1) HEAVY GAGE WIRE. Proceed as follows:

1. Cut insulation proper length.
2. Slide batts of insulation between the joists on top of the wire (Figure 83).
3. Repeat steps 1 and 2, working on areas that are small enough to get the insulation in place easily.
4. End at obstructions such as walls or cross bridging.

Otherwise, the methods of cutting and installing the flexible insulation in floors is similar to that described in section "1. Installing Insulation in the Ceiling."

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b. Loose-Fill Insulation

The only way loose-fill can be used to insulate floors is if a covering has been installed on the under sides of the floor joists. Unless the subfloor has not yet been installed, loose-fill is seldom used for insulating floors.

c. Rigid Insulation

Rigid insulation may be used for the following conditions:

(1) EXISTING SLAB FLOORS that are cold may be made warmer by installing wood sleepers on the concrete, insulation between the sleepers, a vapor barrier over the sleepers and insulation and/or a wood floor with appropriate floor coverings over that (Figure 84).

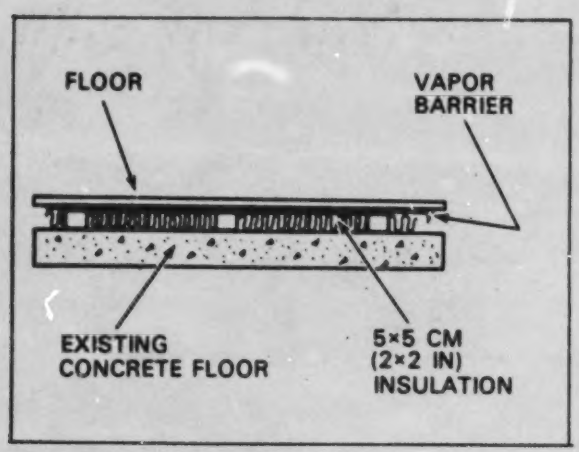

FIGURE 84. Install rigid insulation between vapor barrier and slab.

(2) FRAME FLOORS. In frame floor construction, rigid insulation can be nailed on the underside of the joists. If the insulation does not provide a vapor barrier, one should be installed between the joists and the insulation first.

Less severe problems with cold floors can be helped by using a foam backed carpet as a finish floor covering, or by cementing 3 or 6 mm (1/8 or 1/4 in) felt board to the concrete with a mastic. Finish floor covering then is placed over the felt board.

(3) SLAB FLOORS. Rigid insulations are used primarily to insulate concrete slab floors. Insulations used for such purposes must have strength to resist compression by the weight of the concrete and those objects placed on the floor.

Proceed as follows:

1. Place insulation before concrete is poured (Figure 85).
2. It must extend down inside foundation wall to frost line, or extend horizontally under slab floor for 61 to 91 cm (2 to 3 ft)
3. Rigid insulation may extend under the entire floor.

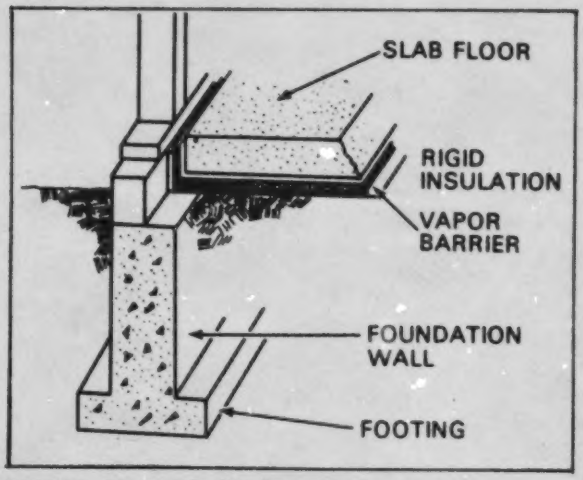

FIGURE 85. Rigid insulation must extend down to the frost line or 61 to 91 cm (2 to 3 ft) under the slab floor.

d. Reflective Insulation

Reflective insulation would be installed in joist spaces in the same manner as it is in ceilings.

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3. INSTALLING INSULATION IN THE WALLS

Any wall which will be exposed to the outside or an unheated area of the building should be insulated. After installing the insulation in the ceilings and floors of a new house, one finds that work on the walls is quite easy. However, extreme care must be exercised in the installation process. There are many more openings around which to work. Electrical wires, electrical boxes and sometimes plumbing must be worked around also.

Installing insulation in walls is discussed under the following headings:

a. Flexible Insulation.
b. Loose-Fill Insulation.
c. Rigid Insulation.
d. Reflective Insulation.
e. Foam Insulation.

a. Flexible Insulation

Batt and blanket insulation is a very popular type of insulation to be used in the walls of houses and additions under construction. The method of cutting and installing batts and blankets in walls is the same as the procedure described in "1. Installing Insulation in the Ceiling." Add the following procedures:

1. Work insulation behind all water and drain pipes (Figure 86).

   Do not pack.

2. Work insulation behind electrical boxes and take care to seal cuts in wall insulation around electrical wires and conduit (Figure 86).

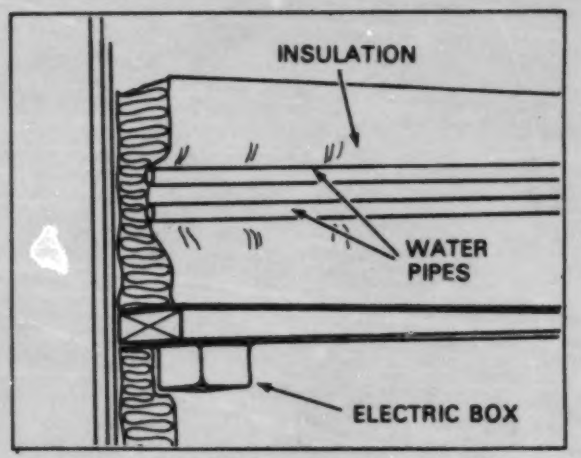

FIGURE 86. Work insulation around pipes and wires.

3. Cut and install insulation in all odd-sized stud spaces no matter how small they are.

4. Completely fill the stud space and staple vapor barrier all around the top, bottom and sides.

5. Stuff cracks between window and door frames and rough openings full of insulation and cover with a vapor barrier (Figure 87).

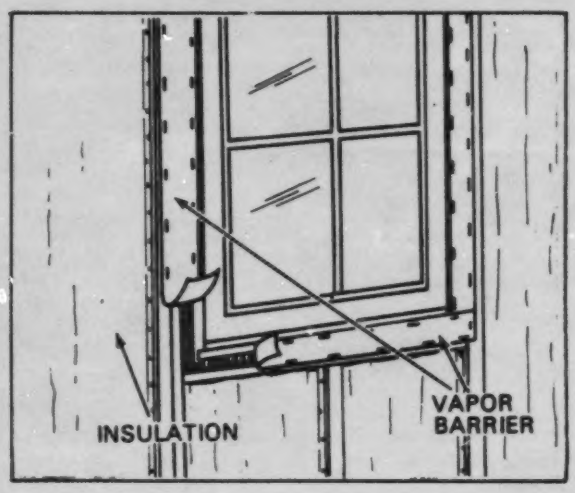

FIGURE 87. Fill all cracks with insulation and cover with vapor barrier.

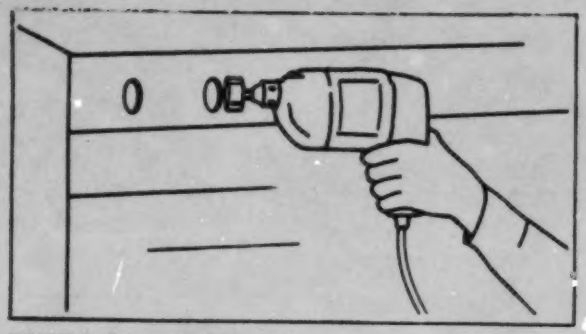

FIGURE 88. Drill hole at top of sheathing.

b. Loose-Fill Insulation

Proceed as follows:

1. Install both ceiling and sheathing and vapor barriers on new construction.

2. Drill hole in sheathing at top of wall (Figure 88).

   On old construction, check for fire stops (horizontal bracing between studs). If they are installed, you will have to fill below them also.

3. Blow in insulation (Figure 89).

   If you are filling the cores in concrete blocks, fill after every 3 or 4 courses rather than wait until wall is completed.

c. Rigid Insulation

The primary use of rigid insulation on frame walls is as a combination sheathing and insulation. In this application, it is usually used together with another type of insulation. The two categories of rigid insulations are insulation boards and foam plastic sheets.

FIGURE 89. Blowing in insulation.

Proceed as follows:

1. Install wind bracing if needed.

   Foam plastic sheets are non-structural so they require that some type of wind bracing be installed in the wall. Some insulation boards have been approved by model codes for use without any other wind bracing, however.

2. Cut insulation boards and fasten to studs in place of sheathing.

   The foam plastic sheets are best cut by scoring the sheet with a utility knife and snapping the sheet in two.

   Nails with 1.1 or 2.5 cm (7/16 or 1 in) heads are required to fasten the sheathing. The following nailing schedule is recommended:

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Fasteners	Crown or Head		Centers	
	cm	in	cm	in
Staples	1.1	7/16	20	8
Staples	1.9	3/4	31	12
Nails	1.1	7/16	31	12
Nails	2.5	1	61	24

If you have masonry walls, glue the insulation boards to the wall. Be sure to use the mastic recommended for the job.

d. Reflective Insulation

Reflective insulations in walls are used primarily to stop the transfer of radiant heat.

Three types are discussed here. They are as follows:

(1) Accordion Type.
(2) Rigid, Reflective One Side.
(3). Rigid, Reflective Two Sides.

(1) ACCORDION TYPE. Accordion-type reflective insulation is pre-made to unfold and staple in a stud space. It must be kept 1.9 cm (3/4 in) away from the inside surface of either wall covering to be effective.

(2) RIGID, REFLECTIVE ONE SIDE. Wallboards, such as gypsum board, and sheathing, such as insulating boards, are available with one reflective side. The reflective side is to be placed toward the inside of the wall. There must be a 1.9 cm (3/4 in) air space between any insulation in the wall cavity and the reflective insulation. Otherwise, they are installed in the same manner as regular wallboards and sheathings.

(3) RIGID, REFLECTIVE TWO SIDES. Insulation, made of a single sheet of material reflective on both surfaces that is installed alone in a stud space should be stapled in place midway between the sheathing and the interior wall covering.

e. Foam Insulation

Two types of foam insulation are the urethane foams and the urea-formaldehyde insulations. Neither of them can be applied without special equipment, as they are made by mixing two components together in an application gun.

They are discussed as follows:

(1) Urethane Foams.
(2) Urea-Formaldehyde Foam.

(1) URETHANE FOAMS. Urethane foam is sprayed on the surface to be insulated. A gas is formed which causes the material to foam and set in a short time. It can be sprayed in the stud spaces to a thickness of an inch or two and does a great deal to give the wall rigidity as well as insulating value. It also can be sprayed on the underside of roofs, etc.

Its application in a closed stud space has been unsuccessful, however, because it is difficult to get the exact amount of mixture between the walls. Too little will leave voids and cause heat loss and too much will expand and push the wall coverings away from the studs.

The material must be protected from light because ultraviolet light causes it to break down. The surface is also extremely flammable and when the material burns the smoke is highly toxic. It is also more expensive than most insulating materials, but it is a better insulator per inch of thickness than most. If the urethane foams are to be used, precautions must be taken to guard against the problems mentioned above.

(2) UREA-FORMALDEHYDE FOAM. The urea-formaldehyde foams are foamed into the wall cavity about as aeresol shaving cream would be. They do a good job of sealing around electrical boxes and other obstructions in the stud space. The material is very light and easily crushed. It also has the disadvantage of shrinking somewhat, causing gaps between surfaces in the stud space through which heat can escape. Two holes are drilled into the sheathing in each stud space and the material is foamed into the bottom hole while the upper hole lets out the air.

4. INSTALLING INSULATION IN THE BASEMENT AND CRAWL SPACE

If a building has a crawl space, the floor above the crawl space can be insulated and the crawl space ventilated or the crawl space itself can be insulated. Good insulation is especially necessary in a crawl space or basement if the crawl space contains heating ducts for the furnace.

Insulating basements and crawl spaces is discussed under the following headings:

a. Flexible Insulation.
b. Loose-Fill Insulation.
c. Rigid Insulation.
d. Reflective Insulation.

a. Flexible Insulation

Basements and crawl spaces in wood framed houses have one part of the structure that is often not insulated. This area is the band joist. Normally at this point there will be only 3.8 cm (1 1/2 in) of lumber plus whatever is used as a siding on the outside. This is usually corrected by stapling flexible insulation in the space between the floor joists (Figure 90).

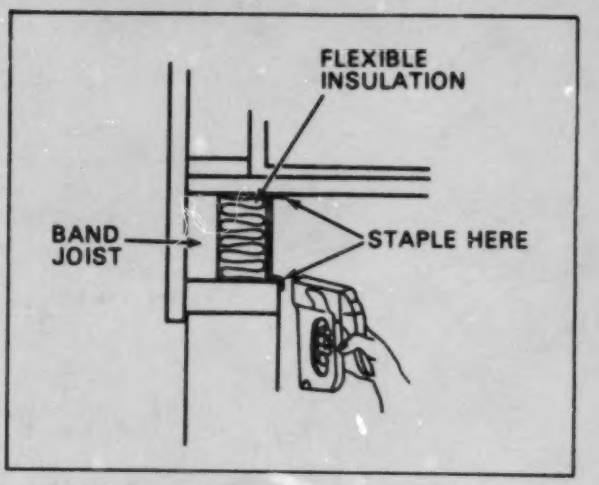

FIGURE 90. Insulate the band joist.

In addition to using flexible insulation at the band joist, it may also be used between furring strips if the basement is finished (Figure 91). In a crawl space, the batt can be stapled to the foundation wall and brought down to the vapor barrier on the ground (Figure 92).

In wood foundations, insulation is installed exactly as it is in any other stud wall.

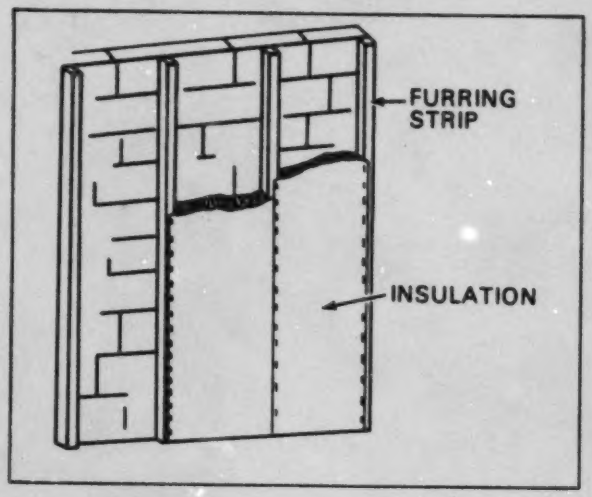

FIGURE 91. Furring strips may be added to a masonry wall to provide for flexible insulation.

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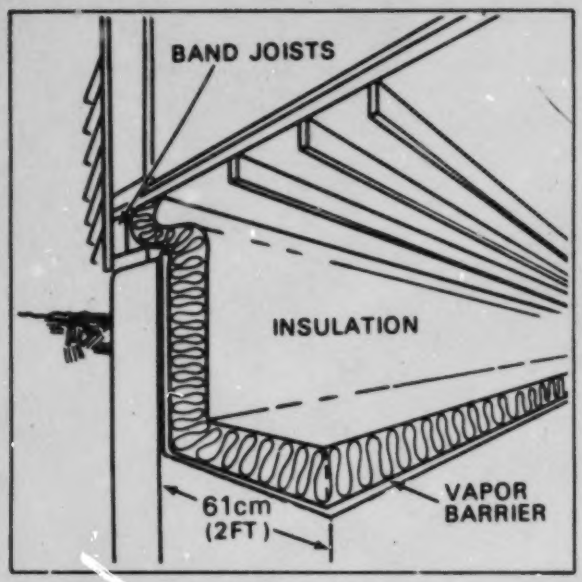

FIGURE 92. Insulation of band joist and crawl space.

b. Loose-Fill Insulation

Except for use as a poor insulation in the cores of concrete blocks, loose-fill insulation has little use in this area of the building.

c. Rigid Insulation

Basements may be insulated by using mastic to glue foam plastic board either to the inside or outside of the wall. If the foam board is glued to the outside, it must be protected from the effects of weather by painting it with a latex texture paint or by applying some other material that is compatible with the foam.

Other types of rigid insulation may be used between furring in basements and on the inside walls of crawl spaces.

Walk out basements must have the exposed part of the basement treated in the same manner as the slab floor described in "A. 2." for rigid insulation.

d. Reflective Insulation

Reflective insulations are seldom used in basements and crawl spaces.

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STUDY GUIDE IV-4-1

Circle the letter(s) that represent the correct answer(s), unless instructed otherwise.

1. The purpose of insulation is to:

   a. Increase heat transfer.
   b. Reduce heat transfer.
   c. Improve appearance.

2. Energy moves from:

   a. A high to a low temperature.
   b. Top to bottom.
   c. A low to a high temperature.

3. Insulation quality is usually based on the amount of:

   a. Glass.
   b. Vapor barrier.
   c. Air space within the insulation.

4. R-value is:

   a. The resistance to air flow.
   b. The rate of heat transfer.
   c. The resistance to energy flow.

5. Types of insulation are as follows:

   a. Fiberglass.
   b. Rock wool.
   c. Cellulose.
   d. Polyurethane.
   e. All of the above.

6. Characteristics of insulation to look for are:

   a. Fire resistance.
   b. R-value.
   c. Form.
   d. All of the above.

7. Forms of insulation are:

   a. Blankets.
   b. Batts.
   c. Loose-fill.
   d. Masonry.
   e. All of the above.

8. Blown-in insulation comes in:

   a. Batts.
   b. Plastic sheets.
   c. Loose-granules or cellulose.

9. Fiberglass comes in:

   a. Rolls.
   b. Batts.
   c. Both.

10. Rock wool is made from:

    a. Rocks.
    b. Wool.
    c. Cellulose.

11. The R-value of insulation sheathing per inch thickness is:

    a. 10.
    b. 6.
    c. 2.

12. Cellulose fiber:

    a. Is fire resistant.
    b. Must be treated for fire resistance.
    c. Comes in batts.

13. Polystyrene has an R-value per inch thickness of:

    a. 4 to 5.
    b. 5 to 10.
    c. 2 to 3.

C. What Construction Materials to Use

(Ref. PROVIDING FOR ENERGY EFFICIENCY IN HOMES AND SMALL BUILDINGS, Part Three, Page 24)

STUDENT STUDY GUIDE OR TEST:

Circle the letter(s) that represent the correct answer(s), unless instructed otherwise.

1. Building materials should have the following characteristics:

   a. Weather protection.
   b. Insulating.
   c. Durable.
   d. Available.
   e. Economical.
   f. All of the above.

2. Fiberglass insulation quality is:

   a. Poor.
   b. Excellent.
   c. Average.

3. Brick and masonry insulation qualities are:

   a. Poor.
   b. Excellent.
   c. Average.

4. Window glass insulation qualities are:

   a. Poor.
   b. Excellent.
   c. Average.

5. Most insulation is:

   a. Simple to install.
   b. Difficult to install.
   c. Neither.

EXERCISE:

Visit your local building supplier and report cost and availability of some building materials.

14. Blue polystyrene has a higher R-value than white.

    a. True.
    b. False.

15. Polystyrene must:

    a. Never be covered with other material.
    b. Always be covered with other material.
    c. Have brick siding.

16. Urea-formaldehyde is:

    a. Blankets.
    b. Blown in.
    c. Sheets.

17. From Figure 3, page 44, indicate R-values recommended for your area:

    a. Ceilings. _____
    b. Walls. _____
    c. Floors. _____

18. Two methods providing more insulation in walls are:

    a. Use 6 inch studs.
    b. Use 4 inch studs and add sheet insulation to outside.
    c. Use 4 inch studs and add blown-in insulation.

E. What Type of Vapor Barrier to Use

(Ref. PROVIDING FOR ENERGY EFFICIENCY IN HOMES AND SMALL BUILDINGS, Part Three, Pages 34-35)

STUDENT STUDY GUIDE OR TEST:

Circle the letter(s) that represent the correct answer(s), unless instructed otherwise.

1. Three types of vapor barriers are:

   a. Polyethylene film.
   b. Aluminum foil.
   c. Paints.
   d. None of the above.

2. Polyethylene film is available in thicknesses of:

   a. 2-6 mils.
   b. 3 1/2 to 4 inches.

3. Paints are used as a vapor barrier:

   a. In old buildings.
   b. In hallways.
   c. In new construction.

EXERCISE:

Visit your local supplier and report on type and availability of vapor barriers.

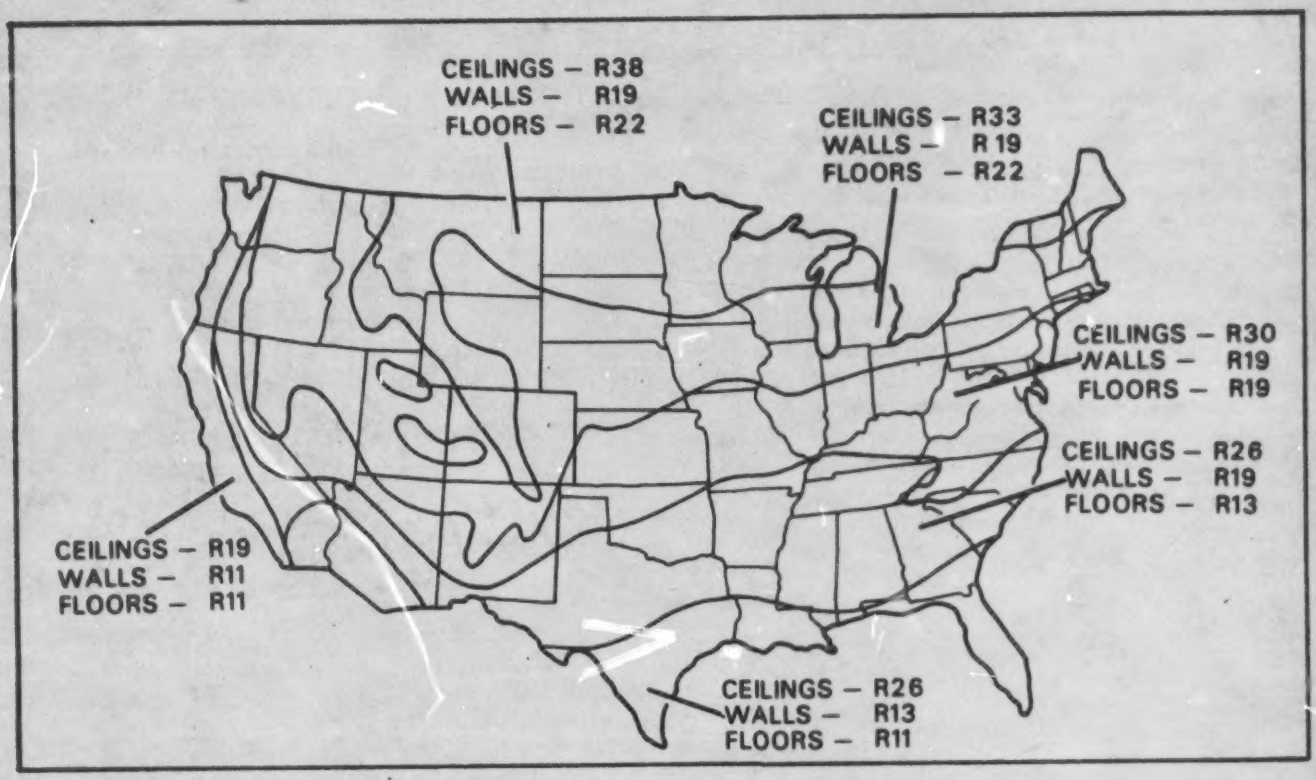
CEILINGS – R38
WALLS – R19
FLOORS – R22
CEILINGS – R33
WALLS – R 19
FLOORS – R22
CEILINGS – R30
WALLS – R19
FLOORS – R19
CEILINGS – R26
WALLS – R19
FLOORS – R13
CEILINGS – R19
WALLS – R11
FLOORS – R11
CEILINGS – R26
WALLS – R13
FLOORS – R11

FIGURE 3

STUDY GUIDE IV-4-2

Circle letter representing correct answer, unless instructed otherwise.

1. Insulation should be installed in floors:

   a. Exposed to unheated areas only.
   b. Wherever they are found.
   c. Only if they are made of hardwood.

2. What types of insulation are generally used in floors?

   a. Flexible.
   b. Rigid.
   c. Reflective.
   d. All of the above.

3. Flexible insulation is easier to install in floors:

   a. Before the subfloor is laid.
   b. After the house is finished.

4. Flexible insulation with vapor barrier backing has:

   a. The vapor barrier installed toward the ground.
   b. The vapor barrier installed next to the heated side.

5. Flexible insulation is supported under finished floors by:

   a. Heavy gage (stiff) wire.
   b. Wire mesh.
   c. Either of the above.

6. Loose-fill insulation is not generally used in floors.

   a. True.
   b. False.

7. Rigid insulation may be used in the following types of floors:

   a. Existing slab floors.
   b. Wood floors.
   c. New slab floors.
   d. All of the above.

8. Rigid insulation is placed under the vapor barrier under concrete slab floors.

   a. True.
   b. False.

9. In Figure 4, indicate type and location of insulation to be installed in the floor.

STUDY GUIDE IV-4-3

Circle letter representing correct answer, unless instructed otherwise.

1. Insulation should be placed in the following walls:

   a. All walls.
   b. Only walls exposed to unheated areas.
   c. Only brick walls.

2. What types of insulation may be used in walls?

   a. Flexible.
   b. Loose-fill.
   c. Rigid.
   d. Reflective.
   e. Foam.
   f. All of the above.

3. If the insulation has a vapor barrier, the vapor barrier should be placed:

   a. Next to the exposed (cold) side.
   b. Next to the heated side.
   c. Doesn't matter.

4. Vapor barrier should:

   a. Have no holes or torn places.
   b. Have holes punched for air circulation.

5. Blanket insulation with a paper vapor barrier (non-foil) backing may be stapled:

   a. To the outside of the stud.
   b. To the inside of the stud.
   c. Either way.

6. If the vapor barrier backing is a reflective foil:

   a. The backing must be stapled to the inside edge of the studs and an air space provided.
   b. The backing must be stapled to the outside edge of the studs.

7. When installing blanket or batt insulation:

   a. Leave spaces between joists for expansion.
   b. Pack insulation tightly around receptacles and pipes.
   c. Place insulation loosely, leaving no space between joists or around receptacles and pipes.

8. Wood is just as good an insulator as fiberglass.

   a. True.
   b. False.

9. Safety equipment to be worn when installing flexible insulation in walls include:

   a. Short sleeve and loose fitting clothes.
   b. Chemical respirator.
   c. Safety goggles, dust mask and clothes that fit tightly around neck and wrists.

10. When installing loose-fill insulation in walls in old buildings:

    a. Fill to fire stop from top.
    b. Fill to fire stop from bottom.
    c. Check for fire stop and fill both sides.

11. When using rigid insulation on walls:

    a. No other insulation is needed.
    b. It is usually used in conjunction with other type insulation.

12. When using rigid insulation:

    a. Corner bracing is usually necessary.
    b. Corner bracing is not necessary.

13. Rigid insulation is available in the following types:

    a. Accordion.
    b. Reflective one side.
    c. Reflective both sides.
    d. All of the above.

14. Urethane foams are sprayed on the job.

    a. True.
    b. False.

15. In Figure 4, page 60, indicate type and location of insulation to be installed in the walls.

STUDY GUIDE IV-4-4

Circle letter representing correct answer, unless instructed otherwise.

1. Insulation should be installed in a new or remodeled building:

   a. As each component part is completed.
   b. After all framing is done and electrical, plumbing, heating and cooling are roughed in.
   c. After the building is completed.

2. The purpose of insulation is to:

   a. Keep out moisture.
   b. Strengthen the structure against wind and snow load.
   c. Improve the thermal efficiency.

3. Insulation should be placed in the following ceilings:

   a. All ceilings.
   b. Only ceilings exposed to unheated attics or directly covered by roofs.
   c. Only ceilings directly covered by roofs.

4. For buildings which have no attic and insulation is installed next to the roof:

   a. Air space is required between insulation and roof.
   b. Air space is not required.
   c. Air space is required between insulation and ceiling.

5. What types of insulation may be used in the ceiling?

   a. Flexible insulation.
   b. Loose-fill insulation.
   c. Rigid insulation.
   d. Reflective insulation.
   e. All of the above.

6. If the insulation has a vapor barrier, the vapor barrier should be placed:

   a. Next to the heated side.
   b. Next to the exposed (cold) side.
   c. Doesn't matter.

7. Vapor barriers should:

   a. Have holes punched for air circulation.
   b. Have no holes or torn places.

8. Blanket insulation comes in rolls up to 3 1/2 inches thick and 16 or 24 inches wide.

   a. True.
   b. False.

9. Batt insulation comes in sections up to 6 inches thick and 16 to 24 inches wide.

   a. True.
   b. False.

10. Blanket insulation with a paper or vapor barrier (non-foil) backing may be stapled:

    a. To the outside of the joists.
    b. To the inside edge of the joists.
    c. Either way.

11. If the vapor-barrier backing is a reflective foil:

    a. The backing must be stapled to the inside edge of the joists and an air space provided.
    b. The backing must be stapled to the outside edge of the joist.

12. When installing a blanket or batt insulation:

    a. Leave spaces between joists for expansion.
    b. Pack insulation in tightly.
    c. Place insulation loosely, leaving no spaces between joists or around receptacles and pipes.

13. When adding flexible insulation to the ceiling:

    a. Lay all blankets or batts parallel to joist.
    b. Lay insulation parallel to joists until space is filled, then lay extra at right angles to joist.
    c. Lay all insulation at right angles to joists.

14. When installing flexible insulation:

    a. Wear short sleeve and loose fitting clothes.
    b. Wear a chemical respirator.
    c. Wear safety goggles, dust mask, and clothes that fit tight around the neck and wrists.

15. When installing flexible or loose-fill insulation in the attic:

    a. Be sure and pack insulation against the cornices to prevent air from entering the attic through the soffit vents.
    b. Avoid restricting attic ventilation through the soffit vents.

16. Recessed light fixtures must be protected against contact with insulation.

    a. True.
    b. False.

17. When using loose-fill insulation, vapor barriers are not required.

    a. True.
    b. False.

18. Loose-fill insulation may be installed by:

    a. Pouring.
    b. Blowing.
    c. Either.

19. Rigid insulation is used:

    a. Where the roof and ceiling structure is one such as cathedral ceilings.
    b. Between stories.

20. A combination of rigid and flexible insulation may be used in sloped ceilings framed with rafters.

    a. True.
    b. False.

21. To be effective, reflective insulation must have an air space between the reflective surface and any other surface next to it.

    a. True.
    b. False.

22. In Figure 4, page 60, indicate type and location of insulation to be installed in the ceiling.

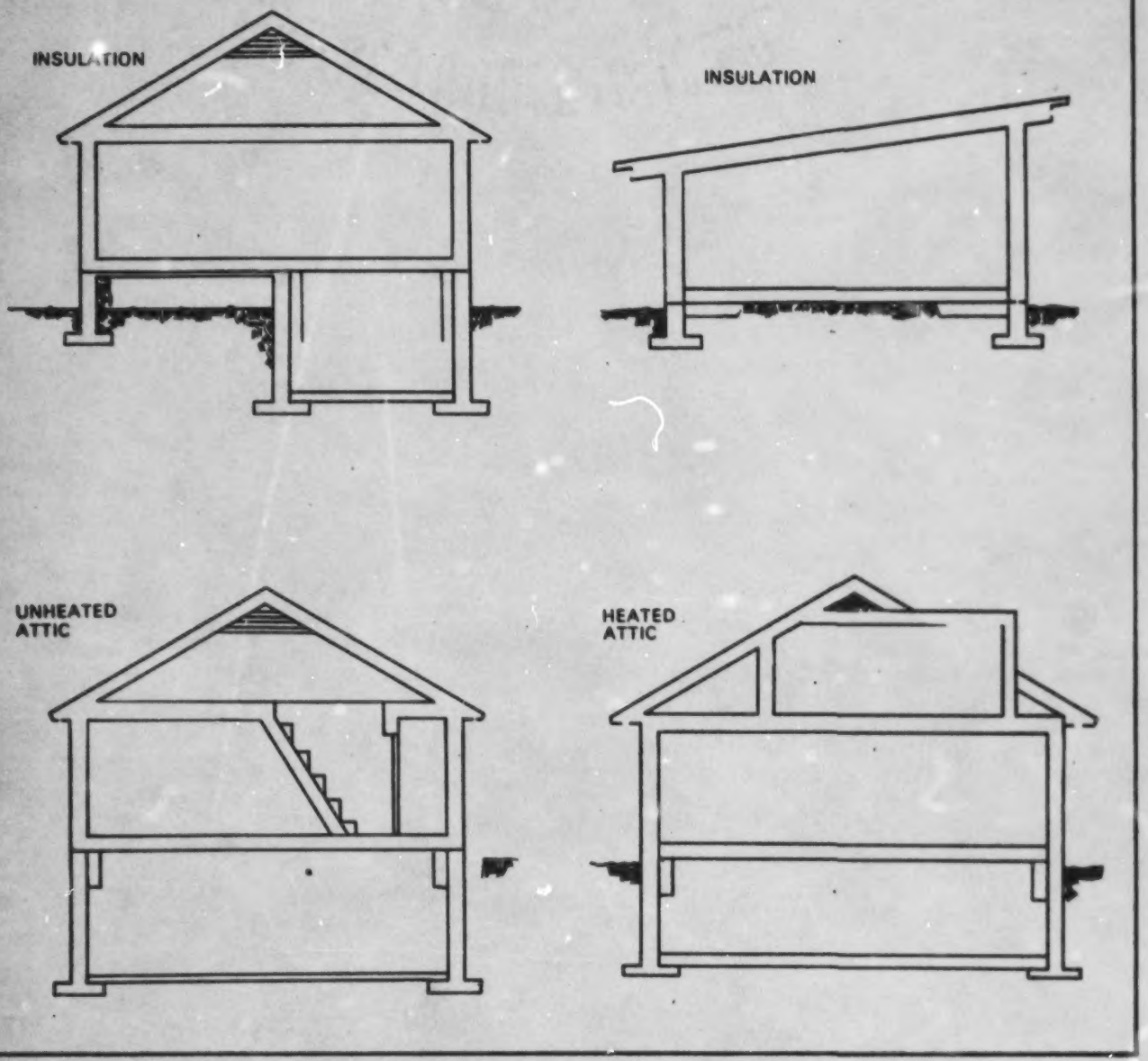

FIGURE 4

Unit IV
Answer Key IV-4-1

1. b
2. a
3. c
4. c
5. e
6. d
7. a b c
8. c
9. c
10. a
11. c
12. b
13. a
14. a
15. b
16. b
17. (see Figure 3)
18. a.b

IV-4-2
1. a
2. 2
3. a
4. b
5. c
6. a
7. d
8. b
9. (See Figure 4)

IV-4-3
1. b
2. f
3. a
4. a
5. c
6. c
7. b
8. c
9. c
10. c
11. b
12. a
13. d
14. a
15. (See Figure 3)

IV-4-4
1. b
2. c
3. b
4. c
5. e
6. a
7. b
8. a
9. a
10. c
11. a
12. c
13. b
14. c
15. b
16. a
17. b
18. c
19. a
20. a
21. a
22. (See Figure 4)

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UNIT IV

FLOORS, WALLS, AND CELINGS

COMPETENCY 5: Select effective vapor barriers.

LEARNING STEPS:

1. Define vapor barriers.
2. Define the various types of vapor barriers.
3. Select the appropriate vapor barrier.

LEARNING ACTIVITIES:

1. Attend a teacher presentation on vapor barriers as an essential part of insulation.
2. Read Information Sheet IV-5-1 "What Type of Vapor Barrier to Use"
3. Define vapor barrier
4. Visit local suppliers and report on the types, availability, and costs of vapor barriers.
5. Answer the questions on Study Guide IV-5-1
6. Read Information Sheet IV-5-2 " Installing vapor barriers"
7. Answer the questions on Study Guide IV-5-2.

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What Type of Vapor Barrier to Use

Vapor barriers are an essential part of the insulation story. Insulation in a wall, ceiling or floor must be protected by a vapor barrier applied to the warm (heated) side of the insulation. Without it, moisture from the house air will enter the insulation, condense and cause serious damage.

Some insulation is sold with an attached vapor barrier. Others require a separate application. Here are some common vapor barrier materials:

1. Polyethylene Film.
2. Aluminum Foil.
3. Paints and Other Finishes.

1. POLYETHYLENE FILM

When insulation without a vapor barrier is installed between studs or rafters, polyethylene is placed (laid or stapled) on the warm side (Figure 29). It is available in convenient rolls in thicknesses from .05 to .15 mm (2 to 6 mils) and in widths from 0.9 to 6.1 m (3 to 20 ft). One tenth mm (4 mil) or thicker plastic is generally used for vapor barrier purposes.

2. ALUMINUM FOIL

Aluminum foil vapor barriers, usually part of insulation rolls or boards, are placed so that they are toward the warm, interior living space. Joints should be taped with aluminized tape to make a tighter air and vapor seal.

In the case of foil-backed gypsum board, the foil side is placed against the wall studs or ceiling rafters which are insulated with a non-vapor barrier material.

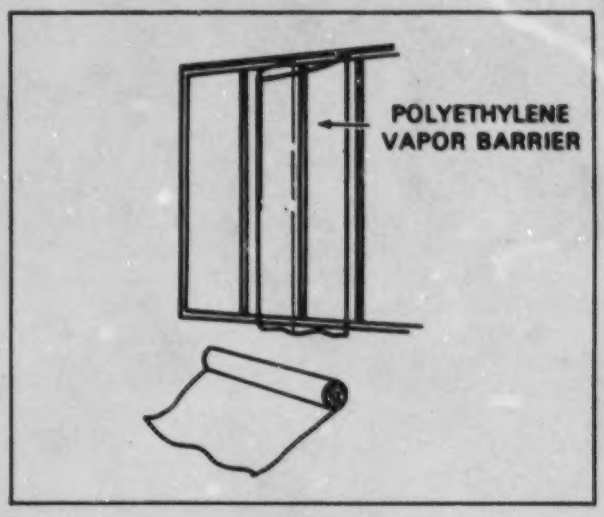

FIGURE 29. Polyethylene film is a good vapor barrier. Use thickness of .5 to 1.5 mm (4 to 6 mils).

3. PAINTS AND OTHER FINISHES

Various paints and other water resistant finishes may be used on interior room surfaces as a moisture barrier when other methods are not feasible—such as in older buildings where interior walls and ceilings are not being replaced. Aluminum paint, rubber base paints, varnish and some urethane finishes serve this purpose.

INFORMATION SHEET IV-5-2

Installing Vapor Barriers

1. INSTALLING VAPOR BARRIERS IN NEW CONSTRUCTION

In new construction, the vapor barrier can either be an integral part of the insulation or it can be a separate layer. If the vapor barrier is part of the insulation, it will be installed with the insulation. The above mentioned precautions are to be followed in this instance, too.

If the vapor barrier is separate, proceed as follows:

1. Use .10 mm (4 mil) polyethylene.
2. Staple it to edges of framing across windows and doors.

   Install on heated side of studs.
3. Tape joints with duct tape.
4. Cut cross-wise and seal around electrical boxes with sealing compound.
5. Seal any tears or holes.
6. Cut out plastic from doors and windows after construction is completed.

2. INSTALLING VAPOR BARRIERS IN EXISTING BUILDINGS

If the building is an existing one and has no vapor barrier, consider the following options:

(1) Interior Walls Good.
(2) Interior Walls Not Good.

(1) INTERIOR WALLS GOOD. Proceed as follows:

1. Add decorative wall covering, or
2. Apply two coats of aluminum primer paint, or
3. Add new wall, or

   Install a vapor barrier on old wall before applying new wall.
4. Provide for ventilation of interior walls.

   Drill holes at top and bottom of each stud space and install miniature vents (Figure 93).
5. Add soffit and attic ridge vents for ventilating the attic.
6. Lay a vapor barrier on the ground in the crawl space.

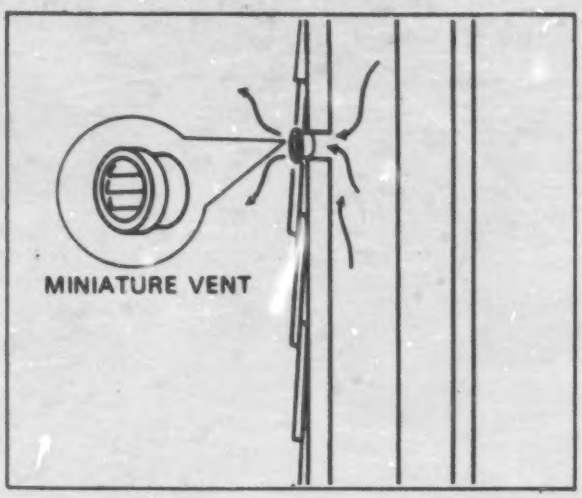

FIGURE 93. Miniature wall vents.

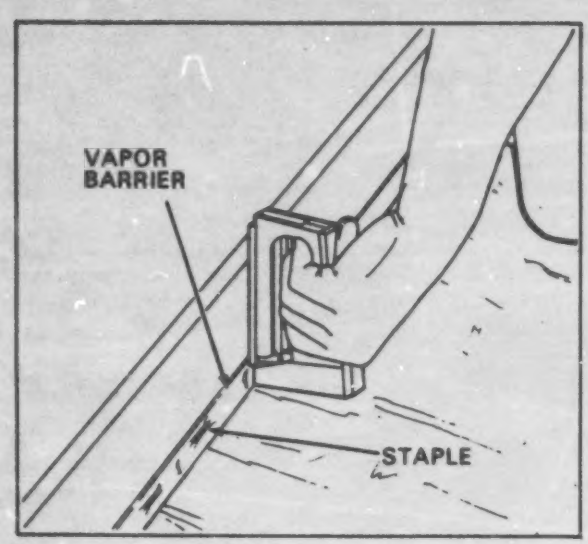

FIGURE 94. Installing vapor barrier in attic.

7. Add ventilation to crawl space.

   Should be equal to 1/1600 of the crawl space area.

8. Install vapor barrier in attic (Figure 94).

9. Install vapor barrier under floor.

   Staple to flow joist on bottom of floor.

(2) INTERIOR WALLS NOT GOOD. Proceed as follows:

1. Remove wall coverings.

2. Install vapor barrier.

   If you need insulation, add insulation. Then attach polyethylene sheets to studs as in new construction.

3. Follow steps 4-9 in previous section.

STUDY GUIDE IV-5-1

Circle the letter(s) that represent the correct answer(s), unless instructed otherwise.

1. Three types of vapor barriers are:

   a. Polyethylene film.
   b. Aluminum foil.
   c. Paints.
   d. None of the above.

2. Polyethylene film is available in thicknesses of:

   a. 2-6 mils.
   b. 3 1/2 to 4 inches.

3. Paints are used as a vapor barrier:

   a. In old buildings.
   b. In hallways.
   c. In new construction.

STUDY GUIDE IV-5-2

Circle letter representing correct answer, unless instructed otherwise.

1. The purpose of the vapor barrier is to:

   a. Prevent water vapor from condensing on the warm side.
   b. Keep insulation dry.
   c. Keep structure dry.
   d. All of the above.

2. Vapor barriers also help reduce air infiltration.

   a. True
   b. False

3. Vapor barriers should have some scatter holes for ventilation.

   a. True b. False

4. Aluminum paint may be applied to old ceilings to provide a vapor barrier.

   a. True b. False

5. Two vapor barriers are better than one.

   a. True b. False

6. Types of vapor barriers are as follows:

   a. Polyethylene film. b. Aluminum foil. c. Waterproof paints and other finishes. d. All of the above.

7. Some insulation is available with vapor barrier attached.

   a. True b. False

UNIT IV

ANSWER KEY IV-5-1

1. a b c
2. a
3. a

ANSWER KEY IV-5-2

1. d
2. a
3. b
4. a
5. b
6. d
7. a

UNIT V

ROOF AND ATTIC VENTILATION

COMPETENCY 1: Select type of ventilation to use.

LEARNING STEPS:

1. Define ventilation
2. Define the basic types of ventilation systems.
3. Learn the ratio of vent area to floor area.
4. Determine the placements of vents to fully utilize the wind pressure and the thermal effect of the building location.
5. Place vents so that elements of weather cannot penetrate the attic.
6. Select the most effective combination of static or natural vents.
7. Select the appropriate power vent, if necessary.

LEARNING ACTIVITIES:

1. Attend a class presentation on "Ventilation" by your teacher.
2. Read the Information Sheet V-1-1 "What Type of Ventilation to Use.
3. Compute the vent area on the problems prepared by your teacher
4. Visit a local supplier and report on types, cost, and availability of static and power ventilators.
5. Answer the questions on Study Guide V-1-1.

What Type of Ventilation to Use

Ventilation is the movement or exchange of fresh air to achieve proper temperature and comfort levels. Ventilation for specific living spaces is necessary for the removal of odors and stale air. Ventilation of an attic or other areas of a building is also necessary to avoid moisture or heat build-up which can result in structural damage and increased energy costs.

To help you gain an understanding of the importance of ventilation and the selection of ventilation systems, the following topics will be included:

1. Types of Ventilation.
2. Effect of Climate.
3. Effect of Efficiency.
4. Effect on Energy Use.
5. Effect on Cost Benefits.

1. TYPES OF VENTILATION

The two basic types of ventilation systems are natural or static ventilation and power ventilation. Window openings are a common method of using natural wind pressure and thermal effect to move fresh air into buildings and hot or stale air out. Static ventilation systems are a common way to provide air changes in attics. Power ventilators which operate electrically are often necessary in conjunction with static systems to achieve the desired results.

They are discussed as follows:

a. Attic Ventilation

Attic ventilation is by static or powered ventilation systems. They are as follows:

(1) STATIC ATTIC VENTILATORS. Static ventilators for attics usually consist of openings with grills, screens or louvered slats which allow air to flow into an attic under the eaves and out of the roof or gable-ends. The factors to consider when selecting ventilators for attic areas are as follows:

- The ratio of vent area to floor area.
- The placement of vents to fully utilize the wind pressure and the thermal effect of the building location.
- The placement of vents so elements of weather cannot penetrate the attic.

The suggested ratio of vent area to floor area is about 1 m^2 (1 ft^2) of net free venting to 150-250 m^2 (150-250 ft^2) of floor area. This ratio should increase as cooling degree days increase (Table XI).

TABLE XI. VENT AREA IN SQUARE INCHES REQUIRED FOR ATTIC FLOOR MEASUREMENTS

Length (ft)	Width (ft)			
	20	30	40	50
20	192	288	384	480
30	288	432	605	720
40	384	576	805	960
50	480	720	1008	1200
60	576	864	1210	1440
70	672	1008	1411	1580

b. Other Ventilators

Other areas of a house besides the attic require ventilation. Basement crawl spaces underneath floors can be a major source of moisture. Ventilators should be installed in the foundation of masonry. Basementless crawl spaces should have net free area of 1/150 of the ground area except when the ground surface is covered with a vapor barrier. If a vapor barrier is used, the ratio can be reduced to 1/1500. The same previous FHA chart can be used to determine the net free area requirement.

Another source of moisture comes from inside a home or building. Often moisture which works its way into and through walls causes blisters and peeling of exterior paint. Paint breather vents or miniature circular louvered vents are used to correct this problem. This method for allowing the walls to "breathe" can also help insulation retain its insulating value and preserve the wall elements from deterioration.

In the laundry, a dryer vent to the outside and perhaps the use of an exhaust fan near the washer will remove excess humidity. Kitchen ventilation systems use either an over-the-stove hood unit or wall-mounted fan to remove odors and moisture from the area.

2. EFFECT OF CLIMATE

There are two basic climatic conditions that exist in every home, summer heat and winter moisture. Ventilation offers an effective means of correcting the problems caused by these two conditions. They are discussed as follows:

a. Summer Heat

Summer heat often builds up in attic spaces to 57°C (135°F), or even 66°C (150°F), when the sun beats down on the roof (Figure 59). This superheated air soon penetrates even insulated ceilings into the living area below. Proper ventilation will greatly increase comfort and substantially reduce air conditioning costs.

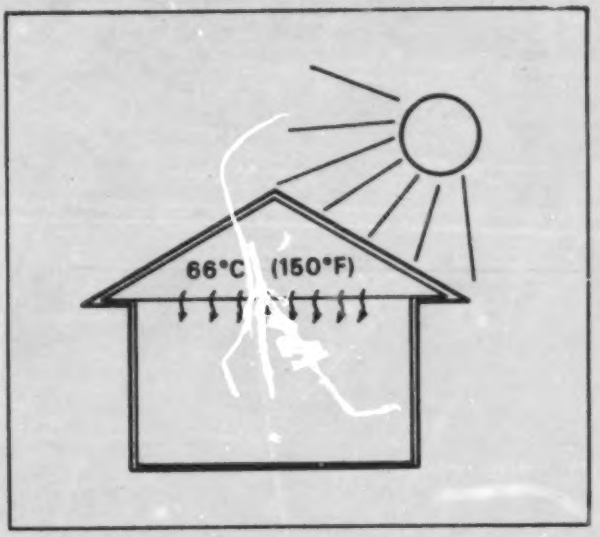

FIGURE 59. Summer heat builds up rapidly in an unvented attic.

b. Winter Moisture

Winter moisture is caused by the use of various household appliances, such as dishwashers, dryers and humidifiers. Daily use of the shower and tub, and cooking vapors all contribute to excessive moisture within your home. When moisture-laden air from the living area rises to the attic, problems will result. This condensed moisture can soak insulation, impairing its efficiency. It can stain or crumble ceilings, and blister exterior paint. Frozen and thawed, it can damage roof shingles. The most effective way to remove excess winter moisture is by proper ventilation.

3. EFFECT OF EFFICIENCY

Watch the EER ratings on your power ventilation. There is a vast difference in electric motor and fan efficiencies.

4. EFFECT ON ENERGY USE

Energy used in a well designed ventilation system is efficient.

5. EFFECT ON COST BENEFITS

The cost of installing and operating a well designed and efficient ventilating system carries a quick return.

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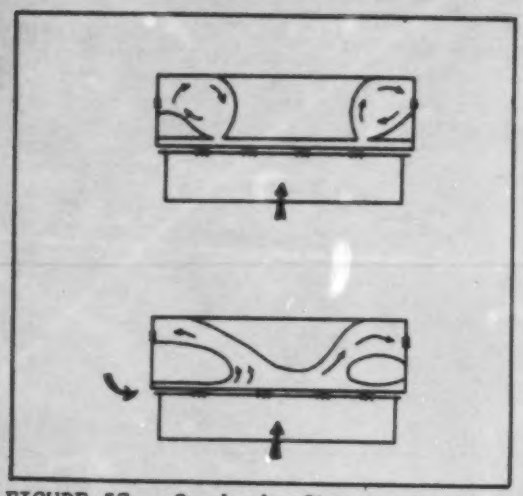

FIGURE 57. Good air flow patterns with gable-end louvers and soffit vents.

(g) Gable-End Louvers with Soffit Vents (Figure 57). Gable-end louver and soffit-vent system does not alter air flow patterns of each unit.

(h) Ridge Vents and Soffit Vents (Figure 58). The continuous ridge and soffit vent combination provides the most efficient system, making the most of the thermal effect, wind pressure and direction.

Given the attic floor measurement, Table XI will help you to estimate the net free-vent area in square inches required. A ratio of 1 to 150 is considered good; a ratio of 1 to 300 is considered an absolute minimum.

(2) POWER ATTIC VENTILATORS. Power ventilators run on electricity and provide effective ventilation with fewer venting holes. Often they are used when no natural ventilating system has been installed. A power ventilator can be controlled by a thermostat or a humidistat to shut off when the temperature is reduced to a desired level. The combination of static vents under the eaves with power vents on the rear slope of the roof near the top (or in the gable ends) can provide a very effective ventilation system.

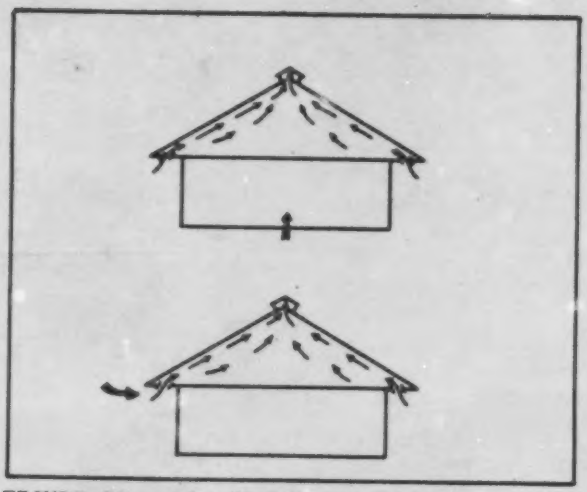

FIGURE 58. Air flow pattern with continuous ridge vents and soffit vents.

An estimate of the power vents is based on achieving at least 10 complete air changes per hour. Table XII can be used to determine the required CFM (cubic feet per minute) rating of a power ventilator for a given attic. Home Ventilating Institute (HVI) standards recommend a minimum of 0.21 m^3/min per m^2 (0.7 CFM per ft^2) of attic floor space, plus 15% for dark roofs.

TABLE XII. RECOMMENDED RATING OF A POWER VENTILATOR FOR ATTIC DIMENSIONS

Length (ft)	Width (ft)			
	20	30	40	50
20	280	420	550	700
30	420	630	840	1050
40	560	840	1120	1400
50	700	1050	1400	1750
60	840	1250	1560	2100
70	980	1470	1950	2450

When placing vents, wind pressure is a most important factor. Wind pressure against one side of a building or roof creates negative pressure areas on the other sides in patterns that draw air out of the building (Figure 50).

No one type of vent will work well alone for the various problems of natural ventilation. They are:

- Wind pressure.
- Thermal effect.
- Radiation heat.
- Wind direction.
- Weather conditions.

Combinations of vents provide for more complete air flow in attic spaces. Some combinations are better than others.

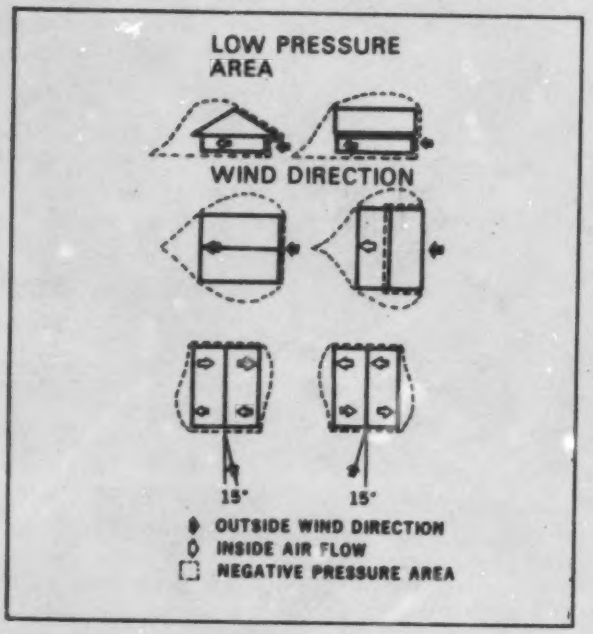

FIGURE 50. Wind creates low pressure areas around buildings that cause air flow.

The thermal effect of hot air rising suggests that high vents allow overheated air to escape while low vents provide cooler replacement air. To allow the net free area to be effective regardless of wind direction, vents are placed as "continuously" as possible.

The various types of static attic vents and useful combinations are described as follows:

(a) Roof Louvers (Figure 51). Usually several of these dome units are mounted near the ridge of the roof. They are made from aluminum, plastic, steel or wood. Aluminum is the least expensive. Screens or slits are used to keep out insects.

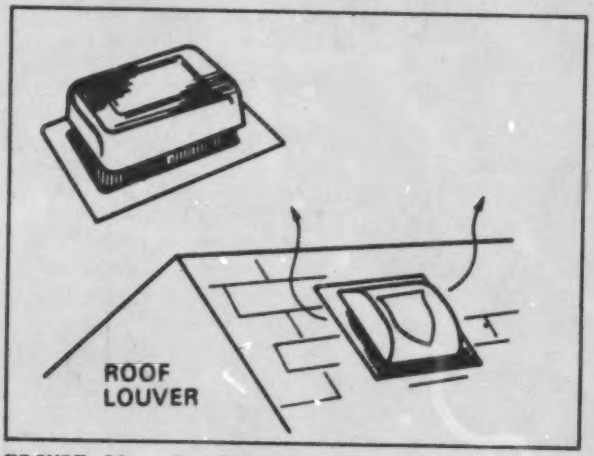

FIGURE 51. Roof louver for static attic ventilation.

(b) Turbine Wheel (Figure 52). This roof louver turns with the wind to more effectively remove attic air. Turbines are not frequently chosen due to the possibility of weather penetration.

FIGURE 52. Turbine wheel for static attic ventilation.

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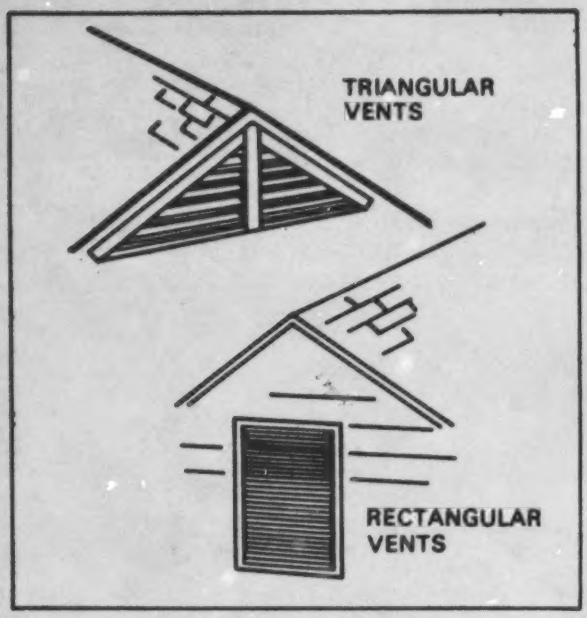

FIGURE 53. Gable-end louver for static attic ventilation.

(c) Gable-End Louvers (Figure 53). Available either in triangular or retangular shapes, they are mounted in or near the top point of the end gables. Air flow varies with the direction of the wind and when used alone they are only somewhat effective. Weather penetration can be a problem if severe. The illustrations show the shapes, placement and wind effects.

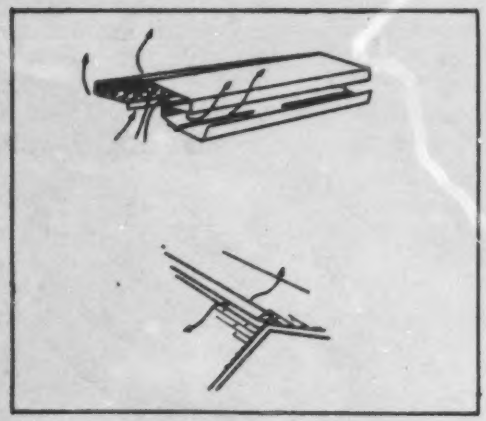

FIGURE 54. Ridge vents for static attic ventilation.

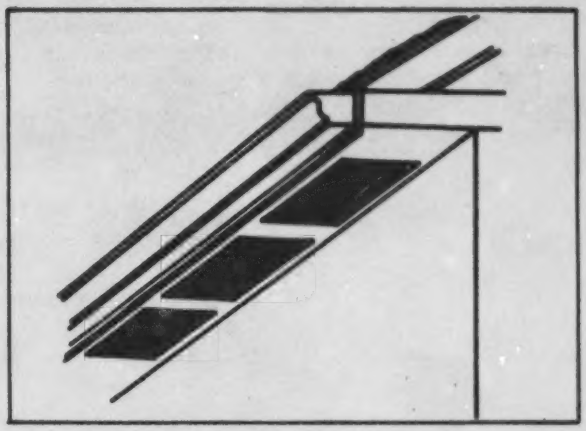

FIGURE 55. Soffit vents for static attic ventilation.

(d) Ridge Vents (Figure 54). This is a continuous opening along the full length of the roof ridge. Net free area is figured at 381 cm^2 (18 in^2) per lineal foot. In conjunction with vents under the eaves, it provides uniform continuous air flow under the roof surfaces.

(e) Soffit Vents (Figure 55). These vents offer effective air circulation no matter what the direction of the wind. They provide only partial ventilation unless combined with roof louvers or ridge vents.

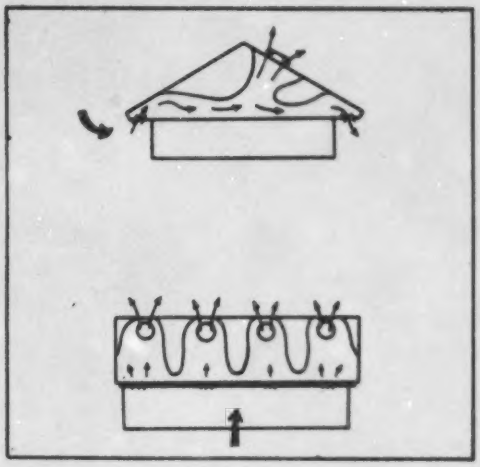

FIGURE 56. Air flow pattern with roof louvers and soffit vents.

(f) Roof Louvers and Soffit Vents. (Figure 56). You will need to balance the air flow with a roof louver and soffit vent system.

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STUDY GUIDE V-1-1

Circle the letter(s) that represent the correct answer(s), unless instructed otherwise.

1. Reduced ventilation saves energy in cold weather.

   a. True.
   b. False.

2. The primary ventilation need is:

   a. Living room.
   b. Attic.
   c. Hall.

3. The main purpose of ventilation is to:

   a. Remove moisture.
   b. Increase moisture.
   c. Improve heating efficiency.

4. Types of attic ventilation are:

   a. Static ventilators.
   b. Power ventilation.
   c. Heat pump.

5. Natural ventilation can be accomplished by:

   a. Thermal effect.
   b. Wind direction.
   c. Wind pressure.
   d. All of the above.

6. Types of static attic ventilators are:

   a. Soffit vents.
   b. Ridge vents.
   c. Electric fan.

7. Power ventilators are to be used:

   a. At all times.
   b. When static systems are not installed.
   c. With cathedral ceilings.

8. Basement ventilators are used to remove:

   a. Moisture.
   b. Dust.
   c. Heat.

9. Static attic ventilators should be used:

   a. Summer only.
   b. Winter only.
   c. Summer and winter.

UNIT V

ANSWER KEY V-1-1

1. b
2. a
3. a
4. b
5. d
6. a
7. b
8. a
9. c

UNIT VI

HEATING AND COOLING EQUIPMENT

COMPETENCY 1: Select the type of heating to use:

LEARNING STEPS:

1. Identify the types of heating systems.
2. Determine the effect of the type of energy available.
3. Determine the efficiency of the system.
4. Calculate the effect on cost benefits.
5. Select the appropriate type of heating system.

LEARNING ACTIVITIES:

1. Attend a teacher presentation on the types of heating systems.
2. Read Information Sheet VI-1-1 "What Type Heating Equipment to Use".
3. Define the types of heating equipment.
4. Visit local suppliers and report on the types, availability and costs of the heating equipment.
5. Answer the questions on Study Guide VI-1-1.

EUALVATION:

Calculate the initial cost of installation and 1 year's cost of operation of several types of heating systems on a given house plan.

What Type Heating Equipment to Use

Central heating systems are the most common method of heating in the United States. In warmer areas of the country, room or zone heaters are sufficient and more flexible. Our choice of a heating system should depend on several considerations. These include both the heating and cooling required for the climate, the type and cost of fuel available and the efficiency and maintenance characteristics of the system.

In this section, the characteristics of the most common heating systems for new construction and the effect on energy availability will be made. With the different system efficiencies to consider and increasing fuel costs, it is important that these factors be understood before new equipment is purchased since heating and cooling systems represent the largest equipment investment in most buildings.

From this section, you will be able to compare types of heating systems and select the most efficient.

1. Types of Heating Equipment.
2. Effect of Type of Energy Available.
3. Effect of Efficiency of the Unit.
4. Effect on Energy Use.
5. Effect on Cost Benefits.

1. TYPES OF HEATING EQUIPMENT

Four main types of heating systems and three minor systems deserve our attention. They are discussed as follows:

a. Electric Resistance Systems

Electric resistance systems—either ceiling cable or baseboard type—convert electric current to heat directly and distribute it primarily by radiation. Electric resistance coils can also be used in a furnace to heat air or water for distribution by ducts or radiators.

The several types of electric resistance heating equipment available are (1) ceiling units, (2) baseboard units, (3) wall units, and (4) an electric furnace.

(1) CEILING UNITS. Electric heating cable is usually laid back and forth on the ceiling surface and covered with plaster or a second layer of gypsum board (Figure 40). There is a thermostat in each room.

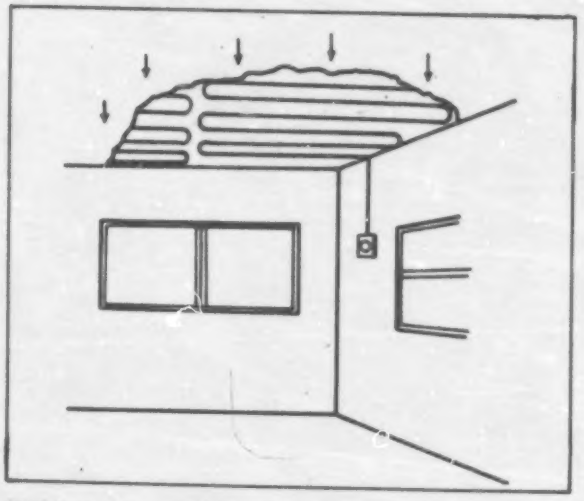

FIGURE 40. Ceiling unit using electric cable for resistance and radiant heating.

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(2) BASEBOARD UNITS. Baseboard heaters take little space (Figure 41). They are convenient to install and are popular for new additions. They send out heat by natural convection or fans. Each unit has its own thermostat and requires very little maintenance.

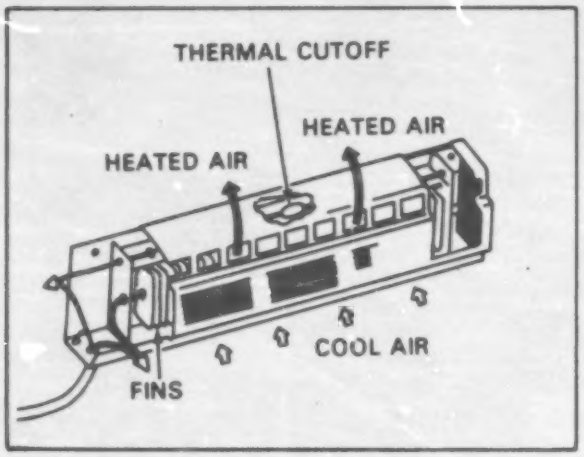

FIGURE 41. Baseboard heater.

(3) WALL UNITS. The electric wall units are designed to be recessed or surface mounted and discharge warm air into a room by means of a fan (Figure 42).

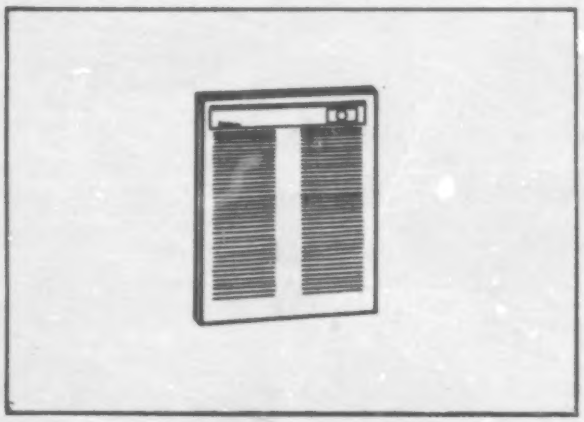

FIGURE 42. Electric wall heater.

(4) ELECTRIC FURNACE. An electric furnace is a very clean operating system since no fuel combustion takes place. Air is blown over heated resistance coils by a fan. Properly installed and insulated ducts will minimize heat loss. The operating costs are usually much higher than other available heating systems. Maintenance is simple and consists primarily of keeping it clean and changing air filters.

b. Gas Furnaces

Natural gas is the most popular source for home heating in areas where gas is available (Figure 43). Natural gas burns cleaner than fuel oil and the furnaces usually have fewer operating difficulties. Any problems typically involve the thermocouple, the pilot, or some aspect of the electrical hookup. The natural gas furnace is less costly to buy and install than an oil furnace but fuel availability and cost may not be any greater advantage than oil in most locations. Gas can provide the heat source for either forced warm air or hot water systems. A chimney flue is required.

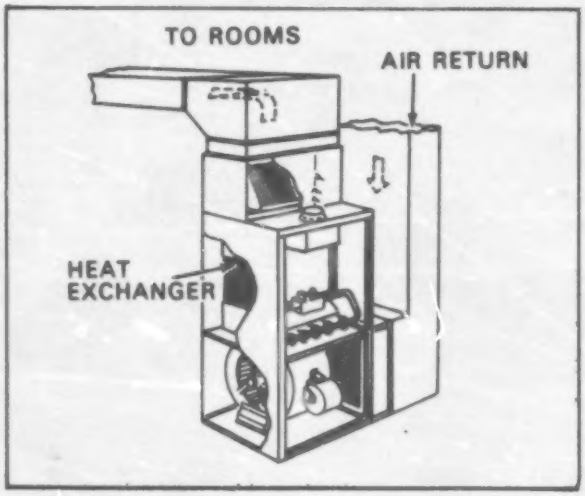

FIGURE 43. A gas-fired, air-circulating furnace.

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c. Oil Furnaces

Oil-fired burners are used in many sections of the country as the basic heat source for a warm air heating system. In an oil furnace, a high-pressure spray combines with a blower to send a fine mist of oil into the combustion chamber, where the oil is ignited by an electric spark. Oil burners are generally reliable but must be maintained properly by a professional on an annual or semi-annual basis.

d. Heat Pumps

The heat pump is another form of electric heating. Recent improvements in units produced by the top manufacturers have made them as reliable as other heating systems. Improvements in newer heat pumps also allow them to be useful in colder climates as well as milder climates. However, since it is usually both a heating and cooling system, the heat pump offers few advantages over conventional heating systems in areas where air conditioning during the spring and summer months is not necessary.

Heat pump operation is based on the same principal as the common household refrigerator or air conditioner. Heat is transferred from one place or source at a fairly low temperature to another at a higher temperature. The most widely used heat pump is the so-called air-to-air unit. It absorbs heat from one source of air and discharges it into another.

The heat pump is both a heating and cooling device and would replace both the furnace and central air conditioner in a typical home.

During the heating cycle, heat is absorbed from the outside air even at temperatures as low as -9°C (15°F). This heat is pumped into the house and the inside blower pushes air across it, removing heat from the coil and heating the inside space (Figure 44).

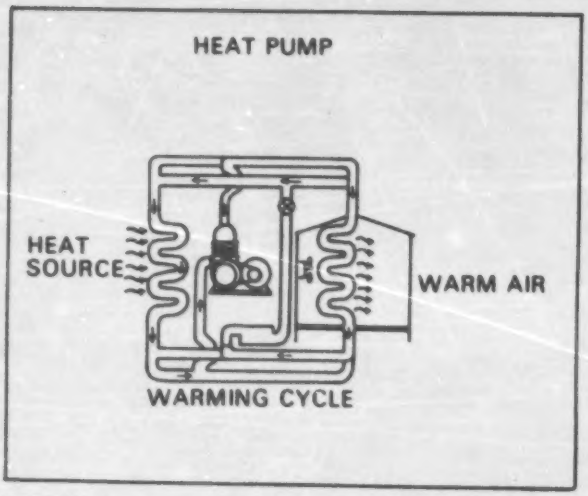

FIGURE 44. Principle of heat pump.

During the cooling cycle, when the house must be air conditioned, cold refrigerant is pumped into the inside heat exchanger coil. A fan blows air from the house across this coil and heats up the refrigerant. Because the refrigerant absorbs heat, it cools off the air.

This refrigerant is a very volatile fluid and as it absorbs heat, it evaporates into a gas inside the coil. This hot gas flows out of the house and into a compressor. The compressor, as its name implies, compresses this hot gas into a super-heated liquid. The hot liquid then flows to the outside heat exchanger coil where another fan blows air across it to remove the heat from the liquid and cool it off.

The significance of the heat pump is its high operating efficiency. For every 1000 joules (Btu) you purchase in the form of electricity to operate the heat pump, you are gaining between 2000 to 3000 joules (2 and 3 Btu) from the outside air for nothing. The heat pump is not a new concept but it is just beginning to gain popularity in parts of the country.

2. EFFECT OF TYPE OF ENERGY AVAILABLE

The major force behind any energy conservation in the home, school or business today is the increasing price of fuel and a concern over its availability in the future. Price controls on natural gas have kept its cost below other heating systems. However, natural gas is increasingly scarce and new hookups are not available in many areas.

Oil is also a popular form of home-heating fuel. Due to cost of getting domestic supplies and imported oil, prices are climbing steadily.

Only a few homes will be able to count on supplies of wood for all or even part of their heating requirement. It will remain a complementary heat source even with the new stoves on the market and improvements in fireplace efficiency. Coal has diminished in use but will receive greater attention again, both for central power plants and home usage.

Electricity is the most available form of energy but it is already expensive due to the fuel required for its generation, transmission losses and growing demand. Improvement in building construction and insulation will contribute to a more economical use of electricity for heating but at present other fuels are suggested.

Let us look at each major heating energy source more specifically:

a. Oil (All Petroleum-Based Distillate Fuels)

Facts about oil are as follows:

- Most common fuel in use.
- Long-term availability in question.
- Cost increasing steadily.
- Simple to transport and store.
- Thermal efficiency of 40-60 percent.
- Initial cost high due to furnace construction and storage tank.
- Maximum efficiency and safe operation depend upon continuous maintenance.
- Improper burning gives off unpleasant pollutants, sulfur-based compounds and particulate matter.

b. Gas (All Utility Gas and LPG, LNG)

Facts about gas are as follows:

- Availability decreasing.
- Costs increasing.
- Transportation and storage is complex.
- Thermal efficiency good--50-70 percent.
- Relatively simple furnace and vent construction.
- Safety precautions stringent for tank storage.
- Burns clean and produces few noxious by-products.
- Simple operation, adaptable for future use with hydrogen or methane-based system.

c. Coal

Facts about coal are as follows:

- Reserves in America offer greatest availability.
- Use will begin to increase again.
- High heat content.
- Requires substantial furnace and flue construction and a controlled supply of combustion air.
- Requires a carefully designed system and proper burning to avoid CO.

- Gives off carbon and sulfur-based pollutants, particulate matter and ash residue.

- Best for large scale heating and production of electricity.

d. Wood

Facts about wood are as follows:

- Oldest and simplest form of organic matter for burning.

- Carefully selected species have high thermal efficiency, burn cleanly, leave a little ash and produce only minor particulate matter.

- Harvesting is difficult and as expensive as oil when purchased.

- May be useful to those in specific locations where it is plentiful.

- Present fireplaces and stoves are inefficient; however, new furnaces and stoves are about 50% efficient.

- Incomplete burning of wood causes deposits of combustible material in flues and stacks if not cleaned out regularly.

- Pipes, stack, and flues must be carefully designed, built and maintained.

- Fire hazard must be of prime concern in design and location.

e. Electricity (Transmission Medium Rather Than Energy Source)

Facts about electricity are as follows:

- Sources are hydroelectric (water power), nuclear or fossil-fueled (coal, gas, petroleum) generating stations.

- Costs are modest to high, depending on locations.

- All fuel sources have serious drawbacks at present.

- Overall efficiency is low, 25-35%.

- Equipment and installation are very flexible and quite simple.

- Resistance heating coils which deliver heat require protection and care in use.

- Lack of source reliability may make electricity very expensive.

3. EFFECT OF EFFICIENCY OF THE UNIT

Researchers at Oak Ridge National Laboratory have calculated overall efficiencies for the common types of heating systems. Table VII compares heating system efficiency with overall energy efficiency.

You can see from the table just how much the efficiency of a heating system affects the total picture. Burning a petroleum-based fuel in a furnace is more efficient than using it to generate electricity. Electrical generation losses are over two-thirds of the input energy of the fuel used. Although the electric resistive heating system is usually considered to be 100% efficient in its heat conversion, its overall efficiency is about half that of natural gas. Since the consumer pays for the fuel cost of electric generation, the cost of electricity remains high despite the high efficiency of the heating system itself.

The heat pump during the heating cycle is most efficient at 7° or 10°C (45° or 50°F) but its efficiency drops as the temperature drops. At 10°C (50°F) you might have a system efficiency of 300% while at -7°C (20°F) the efficiency may be 200%. Even at this efficiency, the heat pump is cheaper to operate than typical resistance heating. Resistance heating can be used as a back-up for a heat pump when the temperature drops below -9°C (15°F).

Since electricity prices range from as little as 3¢ to 8¢ or more per kwh, operating costs are a major factor in the selection of electric systems versus gas or oil.

TABLE VII. COMPARISONS OF HEATING SYSTEM EFFICIENCIES

Heating System	System Efficiency	Overall Energy Efficiency	
Electric	100%	28.1%	
		- Fuel delivery	95%
		- Electric generation	32.5%
		- Electric transmission	91%
		- Conversion to heat	100%
Gas	60%	55.2%	
		- Delivery	92%
		- Furnace	60%
Oil	55%	50%	
		- Delivery	91%
		- Furnace	55%
Heat Pump	200%*	56% (Temperate Zones)	
		- Delivery, generation, transmission of electricity	28.1%
		- Conversion to heat	200%

*Heat pump efficiency varies with outdoor temperature.

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TABLE VIII. SOME COMPARISONS OF ENERGY USES IN HOME HEATING
(BILLION JOULES, MILLION BTU PER YEAR)

(OAK RIDGE NATIONAL LABORATORY)

City	Electric[a,b]				Gas[b]			
	Heat Pump		Resistance		60% Furnace Efficiency		40% Furnace Efficiency	
Atlanta, GA	57	(54.0)	119	(112.9)	65	(61.3)	97	(91.9)
Boston, MA	144	(137.0)	268	(253.9)	145	(137.8)	218	(206.7)
Cheyenne, WY	214	(203.5)	337	(319.4)	183	(173.4)	274	(260.0)
Chicago, IL	192	(182.5)	318	(300.1)	172	(162.8)	258	(244.2)
Dallas, TX	43	(40.3)	91	(86.3)	49	(46.8)	74	(70.2)
Kansas City, MO	124	(117.1)	225	(213.3)	122	(115.8)	183	(173.7)
Knoxville, TN	82	(77.5)	104	(155.0)	88	(83.8)	133	(125.7)
Minneapolis, MN	252	(239.1)	378	(357.8)	205	(194.0)	307	(291.0)
Philadelphia, PA	120	(113.7)	230	(218.4)	125	(118.5)	179	(177.8)
Phoenix, AZ	20	(19.1)	46	(43.3)	14	(23.5)	37	(35.3)
San Diego, CA	9	(8.8)	24	(22.8)	13	(12.4)	20	(18.6)
Seattle, WA	105	(99.5)	236	(223.0)	128	(121.0)	192	(181.5)
Washington, DC	98	(92.6)	195	(185.0)	106	(100.4)	159	(150.6)

[a]10,479 Btu/kWhr utility conversion efficiency.

[b]10% transmission and distribution losses (Oak Ridge National Laboratory).

4. EFFECT ON ENERGY USE

Comparisons of energy used by different sources are given in Tables VIII and IX.

5. EFFECT ON COST BENEFITS

Comparisons of costs for home heating with different methods is given in Table X.

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TABLE IX. RELATIVE ENERGY USE IN HOME HEATING BY DIFFERENT METHODS (NBS)

City	Heat Pump (kWhr)	Resistance Heating (kWhr)	Natural Gas[a] m^3	Natural Gas[a] (10^3 ft^3)	Fuel Oil[b] L	Fuel Oil[b] (gal)
Atlanta, GA	4,640	9,700	1,543	55.1	1,605	424
Boston, MA	11,770	21,810	3,472	124.0	3,607	953
Cheyenne, WY	17,480	27,430	4,368	156.0	4,538	1,199
Chicago, IL	15,670	25,770	4,102	146.5	4,262	1,126
Dallas, TX	3,460	7,410	1,179	42.1	1,226	324
Kansas City, MO	10,050	18,320	2,918	104.2	3,028	800
Knoxville, TN	6,660	13,310	2,120	75.7	2,199	581
Minneapolis, MN	20,530	30,730	4,889	174.6	5,079	1,342
Philadelphia, PA	9,760	18,760	2,988	106.7	3,104	820
Phoenix, AZ	1,640	3,720	594	21.2	617	163
San Diego, CA	760	1,960	314	11.2	326	86
Seattle, WA	8,550	19,150	3,049	108.9	3,168	837
Washington, DC	7,960	15,890	2,528	90.3	2,627	694

[a]37 MJ/m^3 (1000 Btu/ft^3)
[b]38 MJ/L (138,000 Btu/gal)

TABLE X. ENERGY COST FOR HOME HEATING[a] ($/YEAR)

City	Heat Pump	Resistance	Gas[b]	Oil[c]
Atlanta	71.73	139.87	61.25	127.10
Boston	381.12	703.57	284.64	285.85
Cheyenne	288.49	452.73	91.98	359.54
Chicago	240.71	395.84	196.00	337.75
Dallas	36.69	79.17	35.18	97.07
Kansas City	100.53	183.21	75.58	240.13
Knoxville	78.39	156.61	86.68	174.38
Minneapolis	340.17	510.53	218.02	402.51
Philadelphia	231.76	378.23	183.58	245.84
Phoenix	23.46	53.04	24.41	48.77
San Diego	18.28	47.19	14.05	25.71
Seattle	61.57	155.55	158.76	251.02
Washington	189.86	361.31	136.06	208.23

[a]Incremental cost over and above basic electric bill and cost of water heating.

[b]60% system efficiency.

[c]55% system efficiency (Oak Ridge National Laboratory).

STUDY GUIDE IV-1-1

Circle the letter(s) that represent the correct answer(s), unless instructed otherwise.

1. Common types of space heating equipment are:

   a. Electric resistance.
   b. Gas furnace.
   c. Oil furnace.
   d. Heat pump.
   e. All of the above.

2. Electric resistance heating systems may be which of the following types:

   a. Steam.
   b. Baseboard.
   c. Heat pump.

3. The most popular source of space heating are the:

   a. Gas and oil furnaces.
   b. Heat pump.
   c. Hydronics.

4. The heat pump when heating works like a refrigerator in reverse.

   a. True.
   b. False.

5. Heat pumps take heat from the air when temperatures are as low as:

   a. 15°F.
   b. 10°F.
   c. 0°F.

6. Electricity is less efficient because of:

   a. Low efficiency of equipment.
   b. Energy loss in generation.
   c. More costs.

7. Match the following:

   a. Oil.
   b. Gas.
   c. Coal.
   d. Wood.
   e. Electricity.

   __Limited to specific locations.
   __Good thermal efficiency, 50-70%.
   __Most commonly used.
   __Overall efficiency, 25-35%.
   __Reserves offer greatest availability.

8. Which of the heating systems have the greatest potential for overall efficiency?

   a. Electric.
   b. Gas.
   c. Oil.
   d. Heat pump.

9. The total consumption of energy varies in different parts of the U.S.

   a. True.
   b. False.

10. The cost of energy varies in different parts of the U.S. with the different systems.

    a. True.
    b. False.

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UNIT VI

ANSWER KEY IV-1-1

1. e
2. b
3. a
4. a
5. a
6. b
7. 1 d
   2 b
   3 a
   4 e
   5 c
8. d
9. a
10. a

UNIT VI

HEATING AND COOLING EQUIPMENT

COMPETENCY 2: Select the type of air conditioning system to use.

LEARNING STEPS:

1. Define air conditioning.
2. Identify the various air conditioning systems.
3. Define compressor, condenser, expansion valve, and evaporator.
4. Determine the effect of climate on air conditioning.
5. Determine the effect of an air conditioning system.
6. Select the most energy efficient air conditioning system.

LEARNING ACTIVITIES:

1. Attend class presentation of air conditioning systems by guest lecturer or teacher.
2. Read Information Sheet VI-2-1 "What Type of Air Conditioning Equipment to Use if Needed."
3. Answer the questions on Study Guide VI-2-1.
4. Visit a local supplier and report on type of air conditioners available.

EVALUATION:

On a given house plan in a given climate select the most energy efficient air conditioning system.

What Type of Air Conditioning Equipment to Use if Needed

With the high heat and humidity that may be experienced in many parts of the United States in the summer, air cooling or conditioning has become as important as winter heating to many people.

Even though the emphasis should be on conservation, it would be impossible to eliminate the use of air conditioning in many areas. Many locations require cooling to provide comfortable working conditions. At home, cooling of hot-humid air enables people to sleep better and it can mean reduced stress on persons with heart ailments and other medical problems. Air conditioning is often used to prevent deterioration of some clothing, various leathergoods and tools. Research laboratories and various manufacturing processes require air conditioning. The emphasis then is on how to use an air conditioner more efficiently.

From this section, you will be able to list the factors needed in selecting air conditioning equipment. The following topics are included here:

1. Types of Air Conditioning Equipment.
2. Effect of Climate.
3. Effect of Efficiency of the Unit.
4. Effect on Energy Use.
5. Effect on Cost Benefits.

1. TYPES OF AIR CONDITIONING EQUIPMENT

The typical air conditioning system is composed of four separate devices which make up the complete unit. A gas called a refrigerant is compressed in the compressor. Acting like a giant tire pump, the compressor causes the gas to leave under high pressure and at a fairly high temperature. This hot gas is then cooled in a heat-transfer device called a condenser, which looks like an automobile radiator. As it cools in the condenser, the refrigerant gas changes to a liquid while still at high pressure. The liquid then passes to an expansion valve, which permits the liquid to expand into an evaporator or cooling coil. The expansion process cools the coil and it can now pick up heat from air that is moved across it. In doing so, the refrigerant gas is warmed and then recycled in the compressor. The entire refrigerant is tightly sealed. The usual residential cooling unit has the compressor and condenser located outdoors and the expansion valve and evaporator indoors. Figure 45 shows the air conditioner components.

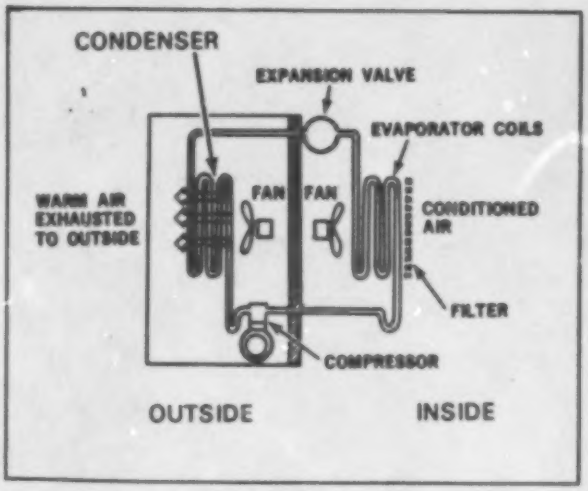

FIGURE 45. How a typical air conditioner operates.

Air conditioners can be installed as part of a central heating system, a separate central conditioning unit or as individual room units. They are discussed as follows:

a. Forced-Air Furnace System

A forced-air furnace system used for both winter heating and summer cooling will have the evaporator located above the furnace casing (Figure 46). As the furnace blower moves warm-room air over the coil, it is cooled and moisture condenses out on the coil. The cooled air then returns throughout the house

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through the same ducts and registers used to deliver heat. When a heating system is planned to accept a cooling system as well, the blower and ducts need to be larger to accommodate the greater air flow requirement of summer cooling as opposed to winter heating. The delivery of heat to a room is usually through registers located at or near the floor since heat rises. In a combined heating/cooling system, the registers may need to be farther up the walls if cooling is a major concern since cool air settles.

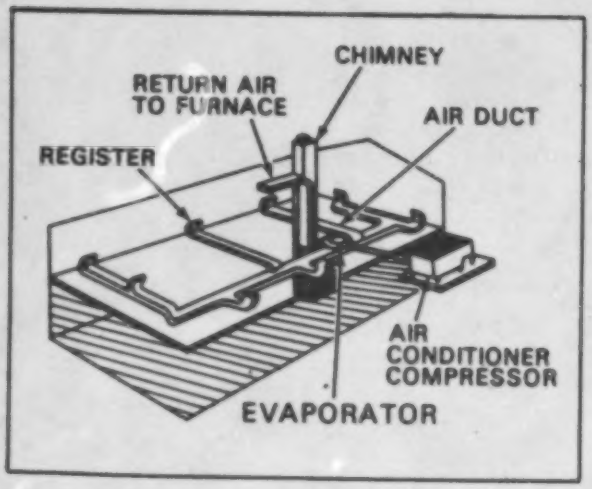

FIGURE 46. Forced-air furnace and air conditioning system combination.

b. Separate Air Distribution System

A separate air distribution system needs to be installed for cooling when hot water or steam heating is used. Often an attic will provide the necessary space for the system and the duct work which can connect to ceiling registers. In this case, a drain line for the moisture condensation from the evaporator leading to the outside is necessary to avoid moisture damage to the ceiling. Heavily insulated duct work and an adequate attic ventilation system are also required for maximum efficiency.

c. Individual Room Units

Air conditioners for individual rooms contain all four parts of the compressor-condenser system in a fairly small package which is installed either in a window or through a wall section (Figure 47). Since these units are in the room they are noisier than central units. They have the advantage of providing cooling when only limited area cooling is required, such as a bedroom for sleeping comfort. People who rent apartments find them convenient when the building as a whole is not cooled.

Check the efficiency rating of your unit. There is a wide variation in operating efficiencies of units.

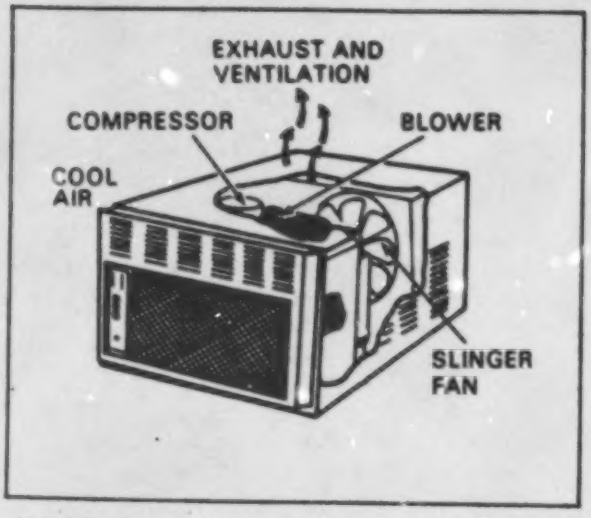

FIGURE 47. Individual room air conditioners.

d. Heat Pumps

Heat pumps, as we indicated, can provide both a winter heating system and a summer cooling system (Figure 48). The operation of the heat pump is like a reversible refrigeration cycle and was illustrated and discussed in Part 1 of the heating section. The initial cost of a heat pump is higher than a conventional heating system but is comparable to a heating system plus central air conditioning.

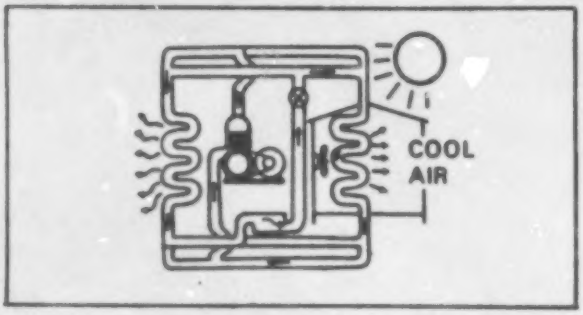

FIGURE 48. Heat pump cooling cycles.

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2. EFFECT OF CLIMATE

Variations in climate cause the temperature fluctuations which require heating and cooling by artificial means to create comfortable living and working environments. However, in some regions cooling to some degree can be accomplished without elaborate equipment.

One method of cooling which can be effectively used in hot-dry desert areas takes advantage of the fact that when water is evaporated, heat is removed from the air. A simple evaporative cooling unit housing a continually moistened pad or filter and a fan will draw the dry air through the pad, cool and humidify it. It is possible to cool 32°C (90°F) air at 10 percent relative humidity to a comfortable 21°-27°C (70°-80°F) and provide a relative humidity of about 40 percent. Remember, this works well in dry areas such as the southwest and is not for humid areas. The purpose of air conditioning is not limited to cooling air but involves controlling humidity and even cleaning or filtering it to some extent.

On a national basis, we use about eleven times more energy for heating than for air conditioning. However, on a regional basis many parts of the country must rely on air conditioning to a much larger degree while others consider doing without it. Climate determines the type and amount of air conditioning required or desired. Some examples are given by region.

The effect of climate on air conditioning is discussed as follows:

a. Cold Climates

In cold climates an air conditioning system would not be required except for 2 to 4 weeks of very warm summer weather. A central air conditioner would be effective but usually not necessary. Reliance on good room units to allow comfortable sleeping may be sufficient. Also, a good attic fan and open lower floor windows can move the -7° to -10°C (20° to 30°F) cooler night air into the house in the evening (Fiugre 49). They may be thermostatically controlled. A well insulated, closed and shaded house will retain the cooler air for much of the next day. Heat pumps are seldom used in cold climates where cooling requirements are low due to the higher cost of the units.

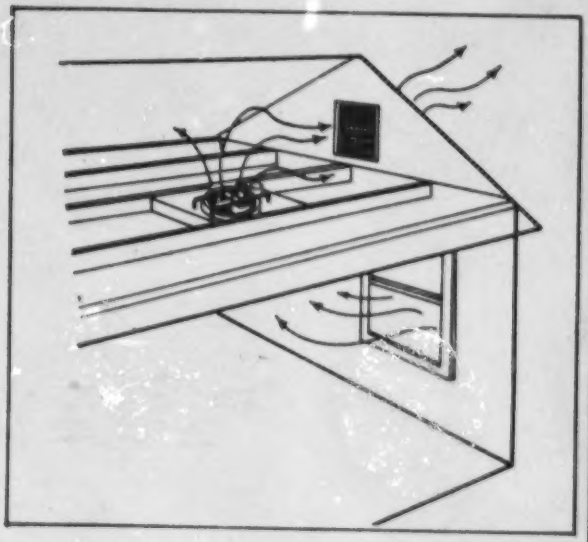

FIGURE 49. Attic fans are effective for cooling in some climates.

b. Temperate Climates

In temperate climates, longer warm or hot periods may warrant a central air conditioning system. However, some of the methods suggested above will work well for buildings protected from direct solar exposure. Heat pumps can be economical because of their more continued use for either heating or cooling and where the average temperature is in the -1°C (30°F) range or higher.

c. Hot-Arid Climates

Hot-arid climates generally require several months of air conditioning along with humidity control. Central air conditioning systems are common as well as the use of individual room units in offices and apartments. Heat pumps are more efficient at these higher temperatures and useful because space heating is still needed for parts of each day over several months.

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d. Hot-Humid Climates

Hot-humid climates also require fairly constant air conditioning for several months. Moisture must be removed from living and working spaces. Again, heat pumps will provide efficient heating and cooling in these areas.

3. EFFECT OF EFFICIENCY OF THE UNIT

Cooling equipment capacity, just like heating systems, is expressed in terms of Btu per hour. In air conditioning or refrigeration 12,000 Btu/hr is equivalent to a 908 kg (1 ton) cooling capacity. This means that a unit with a 12,000 Btu rating has the cooling effect of 908 kg (1 ton) of ice melting. Tonnage ratings are not too useful but simple specification conversion is possible. Also, horsepower ratings are not useful because units with the same horsepower can have very different cooling capacity.

STUDY GUIDE VI-2-1

Circle the letter(s) that represent the correct answer(s), unless instructed otherwise.

1. Parts of an air conditioner are:

   a. Compressor.
   b. Condenser.
   c. Evaporator.
   d. Storage Tank.

2. Types of air conditioners are:

   a. Forced-air system (central).
   b. Individual room units.
   c. Heat pumps.
   d. Fireplaces.

3. An evaporative cooling unit works well in hot-humid zones.

   a. True.
   b. False.

4. Attic fans can be thermostatically controlled.

   a. True.
   b. False.

5. Heat pumps are most desirable in cold climates.

   a. True.
   b. False.

6. When purchasing an air conditioning unit, get the highest:

   a. EER rating.
   b. AVA rating.
   c. Capacity possible.

7. The use of air conditioning in the U.S. is:

   a. Increasing.
   b. Decreasing.

UNIT VI

ANSWER KEY VI-2-1

1. a b c
2. a b c
3. b
4. a
5. b
6. a
7. a

UNIT VII
PASSIVE SOLAR FUNDAMENTALS

COMPETENCY 1: Understanding the principles of passive solar design

LEARNING STEPS:

1. Define passive solar design
2. Determine recommendations for improving the energy conserving capability of a building.
3. Determine the two basic porperties that passive solar systems rely on.
4.

LEARNING ACTIVITIES:

1. Attend teacher's or guest lecturer's presentation of "Principles of Passive Solar Design."
2. Read Information Sheet VII-1-1 "Introduction to Passive Solar Design"
3. List recommendations for improving the energy conserving capability of a building.
4. View the films "The Solar Promise" "If You Can see a Shadow", "The Solar Frontier" "Bill Loosely's Heat Pump" "A Building in the Sun", and "Equal Right to the Sun" available from Bullfrog Films, Oley, Pa 19547 (Rental.)
5. Define "greenhouse effect"

EVALUATION:

List five recommendations to help create an energy conserving structure.
Briefly describe the principles of Passive Solar Design.

The implications of dwindling fossil fuel supplies are creating a marked awareness within the building community of the need to conserve energy in the design of residential buildings. Prospective homeowners are, with increasing frequency, requesting the "energy-efficient" or "passive solar" model. With each revision, building codes and standards become increasingly stringent with regard to the selection of energy use related materials and components. Utilities are providing incentives and assistance, and, in some cases, are requiring that the home builder use energy conservation techniques in new residential construction as a basis for providing service. Significantly, lending institutions are recognizing the financial attractiveness of energy conserving designs which, by reducing operating costs, tend to lower investment risk.

There are numerous techniques and opportunities for conserving energy in residential design. Most remain virtually untapped by the vast majority of home builders nationwide. Simple and familiar techniques, such as increased insulation levels or multiple glazings instead of single glazing are, of course, effective and expedient measures to reduce energy use. These and other energy "conservation" techniques are primarily useful as climatic "buffers," protecting against the deleterious effects of, for example, cold outdoor temperatures. They reduce the demand for energy in the home.

There is, however, a variety of additional techniques which effectively utilize the forces of nature to provide energy to the home, reducing, and in some cases eliminating, the need for conventional fossil fuel fired heating and cooling equipment. In residential design most of these techniques are based upon the use of solar radiation to provide space and water heating, and, occasionally, space cooling. These solar techniques can be subdivided into two basic categories: active and passive. Although the distinction between them is not always clear cut, in general, passive solar techniques or systems heat and/or cool without the need for energy from other nonrenewable sources such as electric power to run a pump. On the other hand, the familiar roof-mounted solar panels, which require pumps and fans whose consumption of electricity may be significant relative to the amount of energy generated by the overall system, are classified as active systems.

In the development of passive solar designs, the range of possibilities should not be limited by strict adherence to this definition of solar types. If a small fan will improve the efficiency of a certain passive installation, it should be used even if the resulting system is not a purely passive one. Similarly, the use of passive techniques should not preclude the use of active components. So-called "hybrid" systems which combine active and passive elements can be very effective at providing a home's energy needs.

It should be emphasized that passive solar techniques are only effective in reducing energy use if they are combined with, not substituted for, standard energy conservation techniques. Any energy gains which a passive system might generate can be easily offset by the energy losses that will occur in a poorly designed and constructed building. It is for this reason that the incorporation of energy conservation measures, in both the design and construction phases of the building, are an absolute prerequisite for an effective passive solar instal-

lation. A partial list of recommendations for improving the energy conserving capability of a building includes the following:

- Insulate the house as well as possible.
- Reduce windows and other openings on the north side of the building.
- Orient the building to maximize the effects of summer breezes and minimize those of winter winds.
- Utilize landscape elements to increase thermal performance by providing shade, blocking unwanted winds, etc.
- Take advantage of overhangs and projections to shade the building during the cooling season.
- Use earth berming where possible to increase the insulating capacity of walls and/or roofs, and to block unwanted winds.
- Ventilate the roof properly to avoid condensation problems and consequent loss of insulating capability.
- Provide adequate vapor barriers.
- Insulate openings by using double or triple glazing or storms on windows and doors.
- Use insulating shades and shutters instead of standard uninsulated units.
- Reduce air infiltration by properly weatherstripping and caulking all openings, and by using proper sill sealers.
- Use air-lock entries.

All of the above recommendations will help create an "energy conserving" structure which will reduce the demand for supplemental energy sources. The next step in the design process is to include passive systems which will allow the structure to actually provide for its own energy requirements. The result will be a truly "energy conscious" home.

Principles of Passive Solar Design

Passive solar systems rely on the intelligent design and organization of the spaces in a home, and the careful selection of building materials, to derive heating and cooling benefits from the free and abundant energy available in the natural environment. Such systems depend on two basic material properties for their effect: (1) the ability of certain materials (predominantly masonry materials) to store large amounts of heat and release that heat slowly to the living spaces of the home; and, (2) the ability of glass and many other glazing materials to transmit solar radiation (light) but to remain opaque to thermal radiation (heat). When a passive system admits sunlight through its south-facing windows, this light strikes objects and surfaces within the space and is transformed into heat. This radiant heat is prevented from passing back out through the windows because the glazing is opaque to this form of radiation. This phenomenon, known as the "greenhouse effect," will be familiar to anyone who has opened the door to a car that has been sitting in the sun with its windows closed on a summer day.

To date, most research and development in the area of passive solar has centered on heating rather than cooling. In fact, the essential processes of a "passive" system (collection and storage) are specifically oriented toward gaining heat rather than rejecting it. This is not to say that aspects of a system cannot be adapted for cooling. Storage elements can be used to store "coolth" and absorb heat from the living space (thereby cooling it) during summer days.

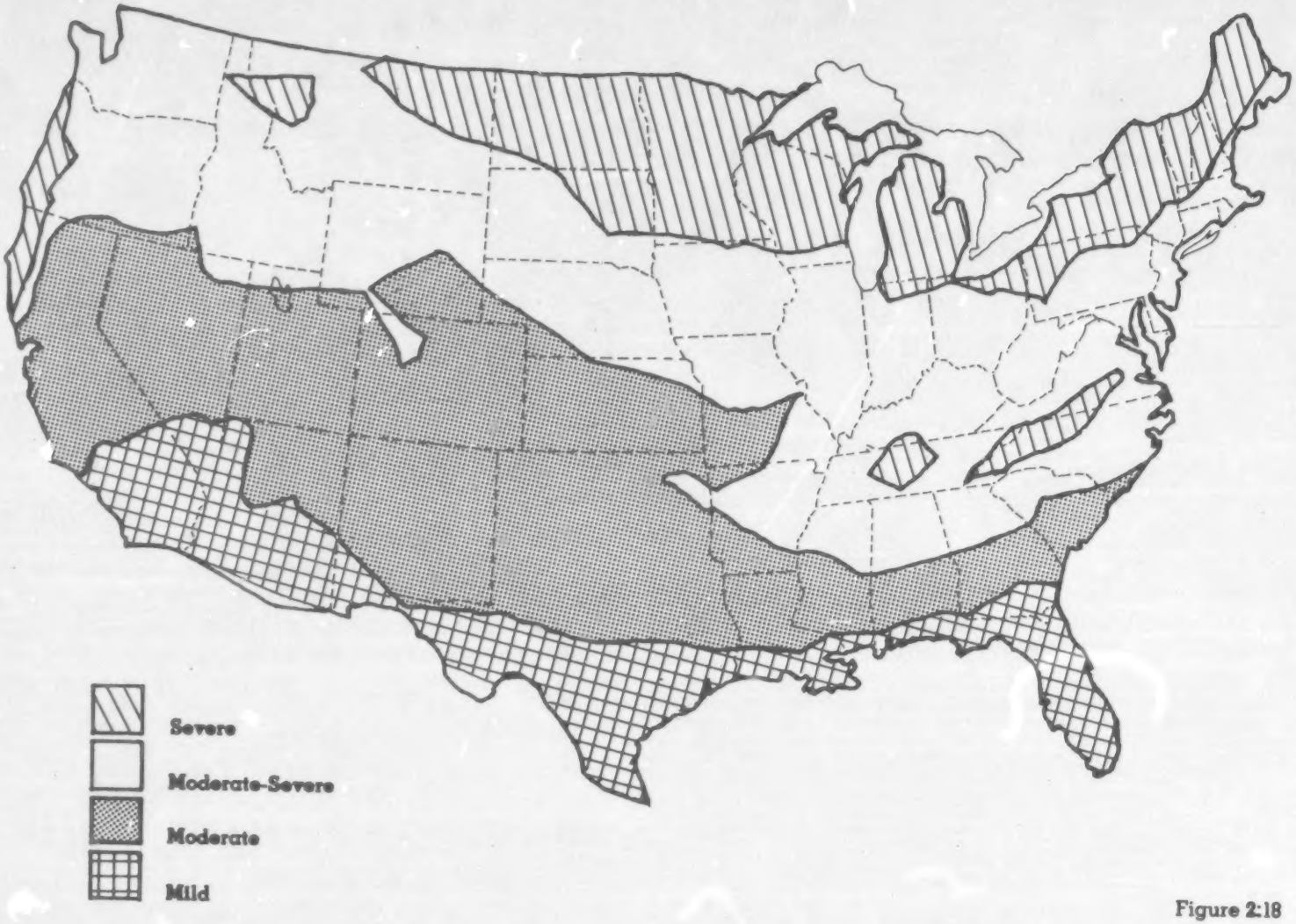


Figure 2:18

UNIT VII
PASSIVE SOLAR FUNDAMENTALS

COMPETENCY 2: Understanding the principles of direct gain.

LEARNING STEPS

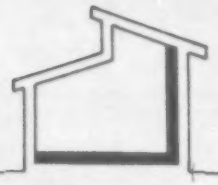
1. Define direct gain
2. Define terms associated with direct gain
3. Identify various applications for a direct gain system.
4. Describe ways to retain heat collected in a direct gain application.
5. Explain the principles of direct gain.

LEARNING ACTIVITIES:

1. Attend teacher presentation on direct gain.
2. Read information sheet VII-2-1 "Basic Passive Systems-Direct Gain"
3. Define south facing glass, clerestories, collector, absorb, storage, direct gain relecting components, distribution, and control components.
4. View 16 mm film "If you can see a shadow." Brewer-Reynolds Productions, Bullfrog Films, Oley, Pennsylvania 19547

EVALUATION:

In your own words, describe or explain the principles of direct gain systems.



Of all the passive solar types a Direct Gain system is perhaps the easiest to envision and construct. A Direct Gain design is one in which solar radiation directly enters and heats the living spaces. The home itself can be visualized as the collector of solar heat. Direct Gain is primarily a heating type system mainly applicable to mild and moderate climates.

In the heating season during the daylight hours, sunlight enters through south facing windows, glass doors, clerestories and skylights, all common collector components in Direct Gain homes. The solar radiation strikes and is absorbed and stored by elements within the space. The most common or primary absorber/storage components within a Direct Gain home are the floors and walls (see Figure 2.1).

Gain storage component materials are most readily incorporated in the floors and walls, which frequently serve a structural function (e.g., a masonry bearing wall). Typically, the distribution of heat is not crucial to the operation of a Direct Gain system as the heat is stored in the same space in which it is used. Heat flow which does occur is by natural convection, usually from one room to another through doorways and stairwells.

In a Direct Gain design, the amount of solar heat which is collected and retained can be controlled by two types of components. During the daylight hours components which reflect sunlight can be placed on the exterior of the home, usually adjacent to the collector components, to increase the amount of solar radiation entering the Direct Gain space (see Figure 2.2).

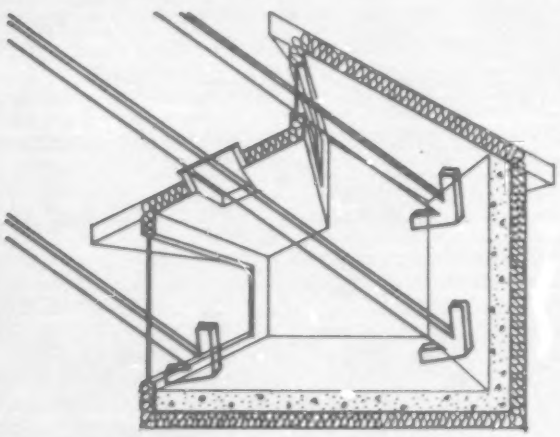


Figure 2.1

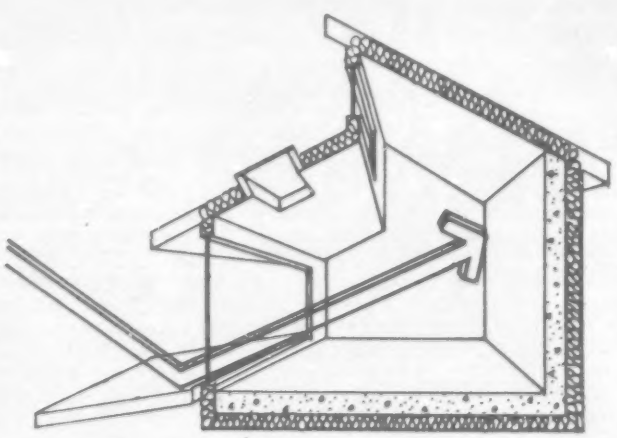


Figure 2.2

Although ceilings and other elements (e.g., furniture) within the space can be designed to store heat, common Direct

Essentially the reflecting component increases the effective collector area without increasing the actual square

footage, and the accompanying heat losses, of the collector.

At night, insulating components can be moved into place to prevent heat flow back out through the collectors. This movable insulation can be mounted either externally or internally. Frequently, in cases where a reflecting component is employed, the reflector serves a dual role by covering and insulating the collector in the evening (see Figure 2.3).

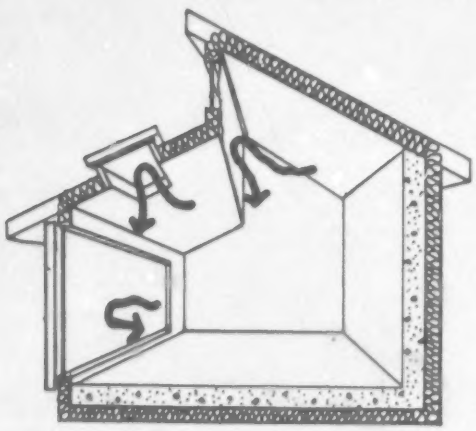


Figure 2.3

During times of the year when heating is not required, the Direct Gain collector should be shaded to control the amount of solar radiation reaching it. The most effective shading components are externally mounted, intercepting the sunlight before it passes through the collector. Interior shades (such as venetian blinds) can also be effective, reflecting some or most of the direct and diffuse sunlight, but will allow some heat build-up to occur. Failure to adequately shade the collectors may result in overheating of the Direct Gain spaces, increasing the cooling load. The movable insulating component can also be used to block solar radiation and reduce heat gain during the cooling season.

UNIT VII
PASSIVE SOLAR FUNDAMENTALS

COMPETENCY 3: Select a method for thermal storage

LEARNING STEPS:

1. Define thermal storage
2. Identify the terms associated with thermal storage.
3. Describe various applications or methods for thermal storage.
4. Select the best method of thermal storage.

LEARNING ACTIVITIES:

1. Attend teacher's or guest's presentation on thermal storage.
2. Read information sheet VII-3-1, "Basic Passive Systems- Thermal Storage".
3. Define storage mass, trombe wall, stagnating wall, radiation, heat transfer, movable insulation.
4. Conduct an experiment on thermal storage using a dark colored brick or a water container painted black inside a room where the sun can strike it through a window. Record termperatures before, during and one hour after it has been exposed to the sun.
5. View 16 mm film " The Solar Promise", produced by Henry Mayer, M.D. Bullfrog Films Oley, Pennsylvania, 19547

EVALUATION:

Given a house plan select the most efficient system of thermal storage.

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A Thermal Storage Wall system is characterized by placement of the storage component between the collector and living space. The storage wall typically provides structural support in addition to serving as the system storage component. Thermal Storage Walls are primarily used to supplement the space heating requirements, with secondary application as a cooling method. In general, Thermal Storage Walls should be considered for areas which experience mild to severe winters.

In the heating season solar radiation is allowed to pass through the collector glazing and is absorbed and stored by the wall. The wall heats up, transferring some of its heat to the living space and some to the column of air between collector and wall. This column of air can be exhausted directly into the living space, in which case it is referred to as a "vented" or "trombe" wall (see Figure 2.4); or can simply remain trapped between the glazing and the wall, in which case it is an "unvented" or "stagnating" wall (see Figure 2.5).

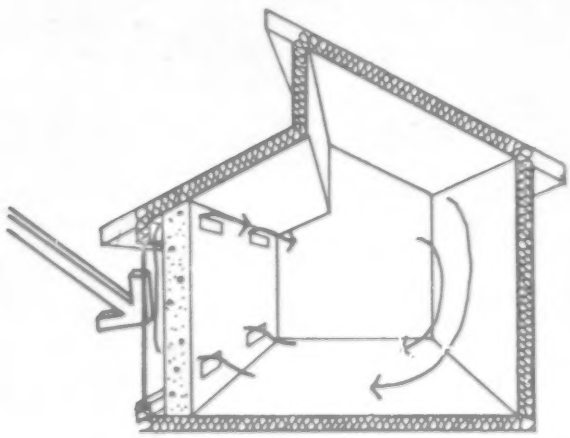


Figure 2.4

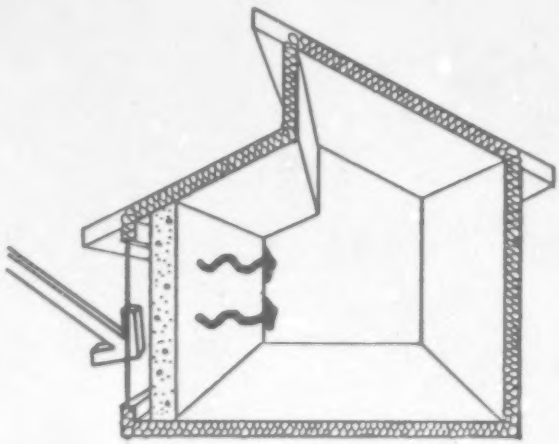


Figure 2.5

In both cases the heat in the wall will radiate to the adjacent living space throughout the day and evening hours.

Beyond the action of the vents in the "trombe" wall, distribution components are not fundamental to either type of Thermal Storage Wall. In some cases warmed air is ducted from the airspace between the collector and storage wall to remote living spaces, but this is not characteristic of the system operation and should be avoided if possible.

In a manner similar to the operation of the Direct Gain system, the performance of the Thermal Storage Wall can be regulated by control components. During the heating season, a reflector can enhance the amount of solar radiation striking the wall and, in the evening hours, an insulating component can be

placed either between storage and collector or outside the collector component to reduce heat flow from the wall to the exterior (see Figures 2.6 and 2.7).

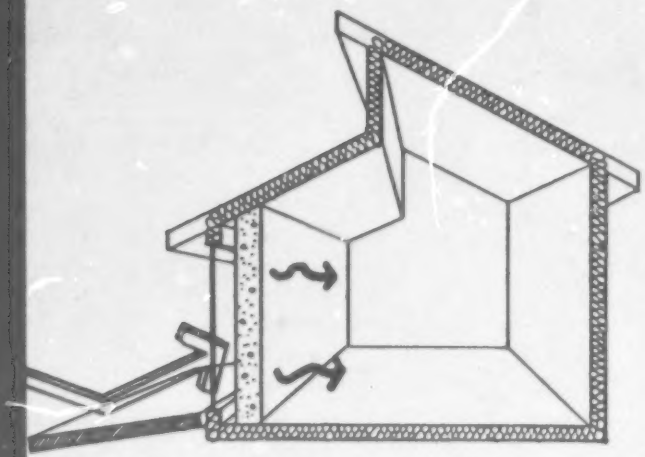


Figure 2.6

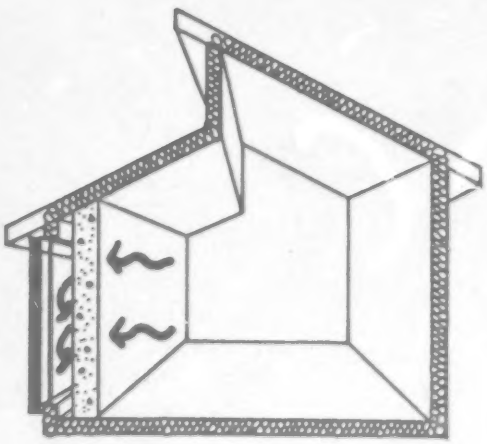


Figure 2.7

In the cooling season the impact of solar radiation should be controlled by shading the collector and storage components. Shading components are most effective when placed on the exterior but can also be installed between the collector and storage wall (see Figure 2.8).

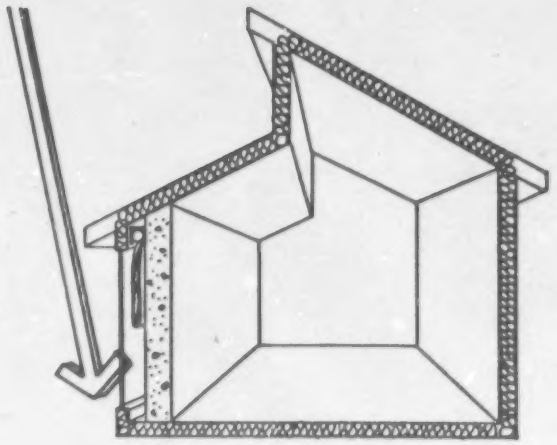
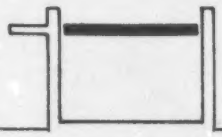


Figure 2.8

If designed properly, the movable insulation used to control nighttime heat flow out of the home during the heating season can be operated in the daytime during the cooling season to control unwanted solar heat gain. To further promote cooling, the airspace between collector and storage components can be vented to the outside. This is particularly effective in regions where the nighttime temperatures drop below the indoor temperatures. Venting the airspace will cool the storage wall in the evening, allowing it to absorb heat from the space during the day, reducing the space cooling requirements.



As the name implies, the storage mass in a Thermal Storage Roof system (usually water or masonry) is located on the roof of the home. It is typically supported by some form of roof decking (metal or concrete) which serves as the ceiling for the space below and which provides for the efficient and even transfer of heat from the mass above. The location and operation of the storage component make Thermal Storage Roofs an appropriate passive system type for desert climates, where they can provide both effective heating and cooling.

Thermal Storage Roofs are unique in that they do not require a collector component. During the day, the storage component is simply exposed to the sky and heated by direct radiation from the sun. This heat is stored and slowly transferred through the ceiling deck to the living spaces below (see Figure 2.12).

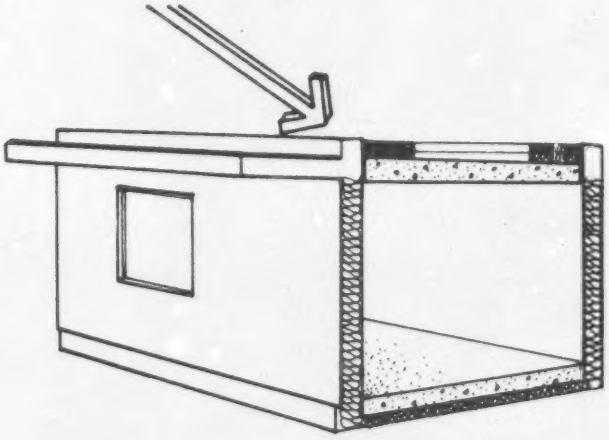


Figure 2.12

At night and during prolonged overcast periods, some form of movable insulation is provided to cover the storage component and reduce heat losses to the cool night sky and air (see Figure 2.13).

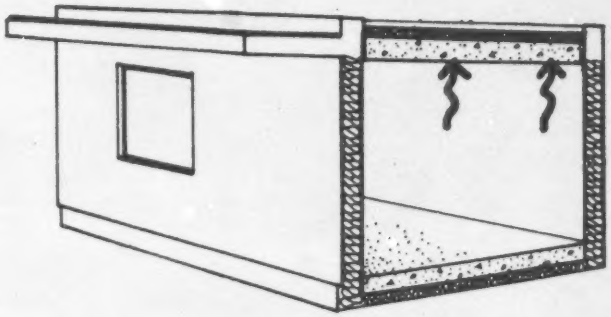


Figure 2.13

The primary control component is movable insulation which is typically mounted on tracks and moved into position using a small motor. Reflectors may be desirable to increase solar radiation during the heating season when the sun is low in the sky.

Of all the basic passive systems Thermal Storage Roofs are perhaps the most effective technique for providing passive cooling. During the cooling season, in areas with high diurnal temperature swings and clear night skies, the exposed storage component will be cooled at night. Loss of the collected "coolth" can be controlled by movable insulation which is placed over the storage component during the daytime to provide insulation and shading. The storage component will absorb heat from the living area during this period, and will effectively

cool the living space. At night the insulation is removed and the diurnal cycle is repeated (see Figures 2.14 and 2.15).

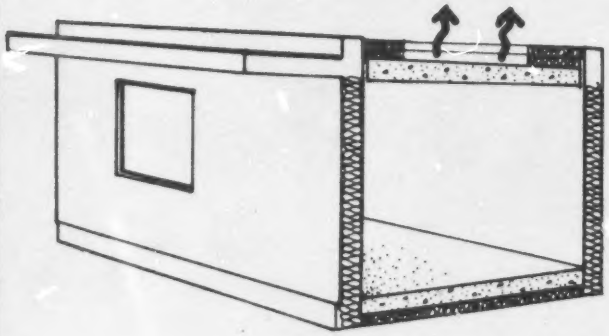


Figure 2.14

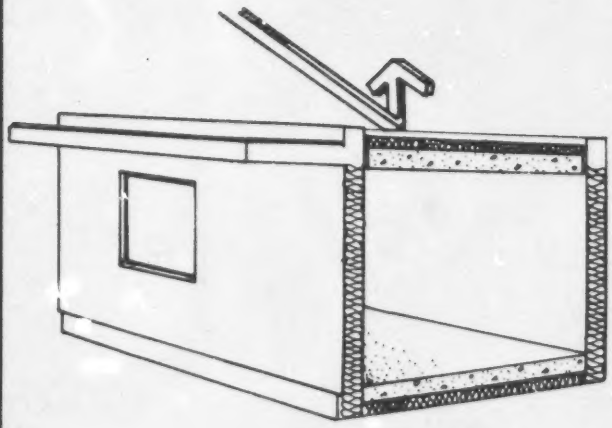


Figure 2.15

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UNIT VII
PASSIVE SOLAR FUNDAMENTALS

COMPETENCY 4: Select an attached sunspace

LEARNING STEPS:

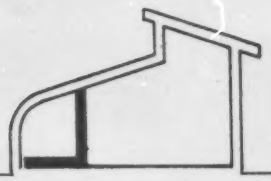
1. Define attached sunspace
2. Determine the basic subsystems for attached sunspaces.
3. Describe various applications for an attached sunspace.
4. Determine the advantages and disadvantages of the various attached sunspaces.
5. Select the most energy efficient attached sunspace.

LEARNING ACTIVITIES:

1. Attend teacher's presentation on attached sunspaces.
2. Read Information Sheet VII-4-1 "Basic Passive Systems-Attached Sunspace."
3. List advantages and disadvantages of attached sunspaces.
4. Explain or describe the basic subsystems of attached sun spaces.
5. View 16 mm film "Equal Rights to the Sun", Bullfrog Films, produced by Bonnie Symansky, Oley, Pennsylvania 19547.

EVALUATION:

Given a house plan and climate conditions, select the most energy efficient attached sunspace.



Attached Sunspaces are typically built as glass enclosed spaces, frequently constructed as extensions to homes. They are generally considered secondary use spaces in which heat is collected and either stored for later use or exhausted directly into the living space. The solar energy collected and absorbed by an Attached Sunspace is used to heat both the Sunspace itself and the adjacent living areas. The ways in which this energy is stored and distributed form the basis for distinguishing five separate Attached Sunspace "subsystems" which differ significantly from each other in terms of their operation, construction, and configuration of basic components. These are:

1. Open Wall Subsystem
2. Direct Gain Subsystem
3. Air Exchange Subsystem
4. Thermal Storage Wall Subsystem
5. Remote Storage Subsystem

During the heating season, sunlight enters the Attached Sunspace through the south facing collector (an expanse of glass or plastic), is absorbed by elements within the Sunspace, and is converted to heat. This basic process is the same for all the Attached Sunspace subsystems. It is only in the operation and location of the storage, distribution and control components that these subsystems differ significantly from each other (for further information see Section 3.3000).

All Attached Sunspaces will be designed for one of two basic modes of operation. In the first, the Sunspace is thermally isolated from the living area (see Figure 2.9). As a result of this isolation, the Sunspace is not treated as a conditioned space and its temperature is allowed to fluctuate outside the comfort range (e.g., during the night).

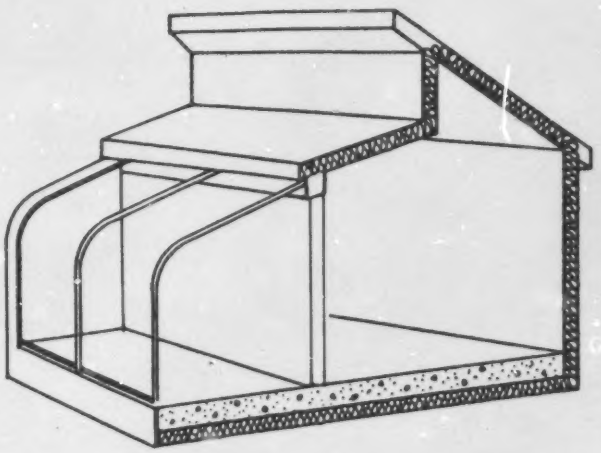


Figure 2.9

In the second mode, the Sunspace is not thermally isolated but is treated as an additional living space (see Figure 2.10).

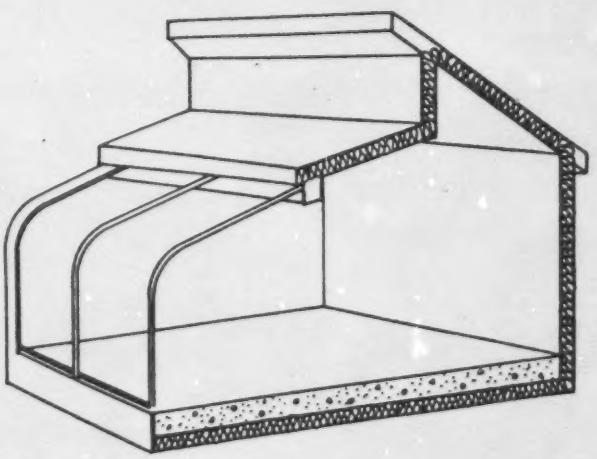


Figure 2.10

In this case, temperatures are not allowed to fluctuate but are maintained, by an auxiliary energy system when necessary, within the comfort range.

Similarly, the design and selection of the control components will vary with the selection of subsystem and operational characteristics. To prevent heat loss, a movable insulating component is typically placed along the collector glazing or between the Sunspace and adjacent living spaces depending upon the type of operation (see Figure 2.11). It is also possible to enhance solar heat gain by the use of a reflecting component.

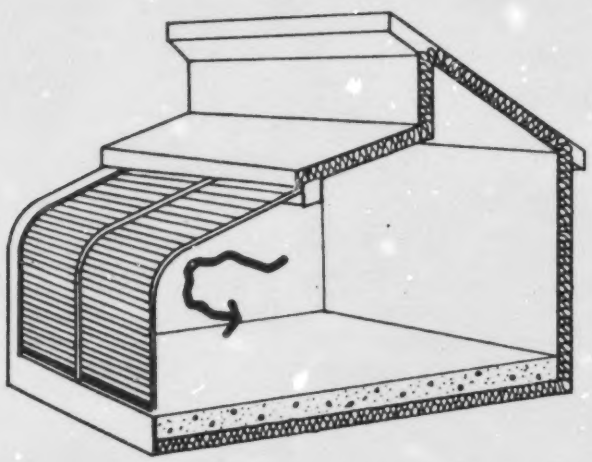
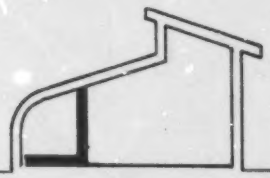


Figure 2.11

In the cooling season, the Attached Sunspace is particularly susceptible to overheating. Control of solar heat gain by shades and ventilation is critical to proper system functioning. In climates where the nighttime temperatures drop below comfort levels it is often possible to use the Attached Sunspace mass for storing "coolth," reducing daytime cooling loads.



Design Overview

Attached Sunspaces are designed to be used primarily for heating and are effective in areas with moderate to severe winter climates. As the name implies they are spaces designed for passive solar gain that are "attached" to the south side of a building. Such spaces often serve as working greenhouses. In these cases they are referred to as "attached greenhouses" or "solar greenhouses," to distinguish them from the standard, "non-solar" varieties which are generally not as well constructed and detailed (see Figure 3.32).

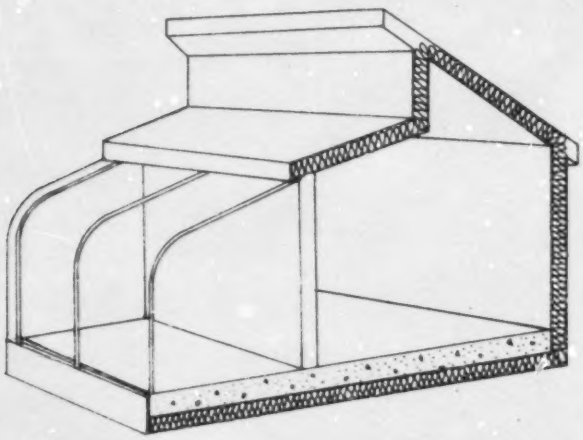


Figure 3.32

A Sunspace can project from the house or the house can be designed to "wrap around" the Sunspace and partially enclose it. The latter configuration has the advantages of: (1) reducing heat losses from both the Sunspace and the house; (2) transferring heat easily to a greater area of the surrounding house; and, (3) allowing for the inclusion of a larger amount of thermal storage material than is possible in a projecting Sunspace. Whether they project from the house or are enclosed by it, Attached Sunspaces can have two basic floor configurations. In the first and most common, the Sunspace floor is level with, or only slightly below or above, that of the living area. In the second, the so-called "pit" Sunspace, the floor level is located below the frost line and thus significantly below the floor of the adjacent living spaces. The "pit" variety has the advantage of increased headroom and of reduced floor and perimeter heat losses due to the relatively constant temperatures of the surrounding earth. A "pit" Sunspace can actually gain heat from the ground in winter if, as is often the case, the temperature in the Sunspace is allowed to drop below the surrounding subsurface ground temperature. In these instances the Sunspace floor slab need not be insulated (see Figure 3.33).

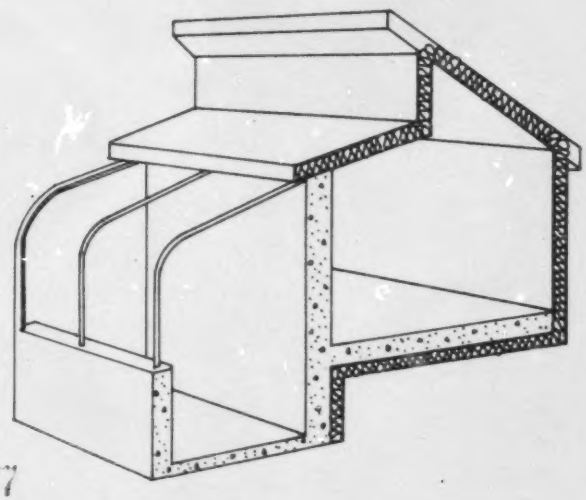


Figure 3.33

The solar energy collected and absorbed

Introduction

by an Attached Sunspace is used to heat both the Sunspace itself and the adjacent living areas. The ways in which this energy is stored and distributed form the basis for distinguishing five separate Attached Sunspace "subsystems" which differ significantly from each other in terms of operation and construction: Open Wall, Direct Gain, Air Exchange, Thermal Storage Wall, and Remote Storage. Where appropriate in this Section, each of these subsystems is treated separately, with the Key Pages organized to reflect this "subsystem," rather than "component" orientation (i.e., each subsystem has its own Key Page and Index to Details).

There are two basic modes of operation for any Attached Sunspace subsystem. In the first, the Sunspace serves as an extension of the living area. It is not thermally isolated from the living space and its temperature is not allowed to fluctuate outside the comfort range. In most cases, this type of Sunspace will require some form of auxiliary energy system to maintain comfortable temperatures (see Figure 3.34).

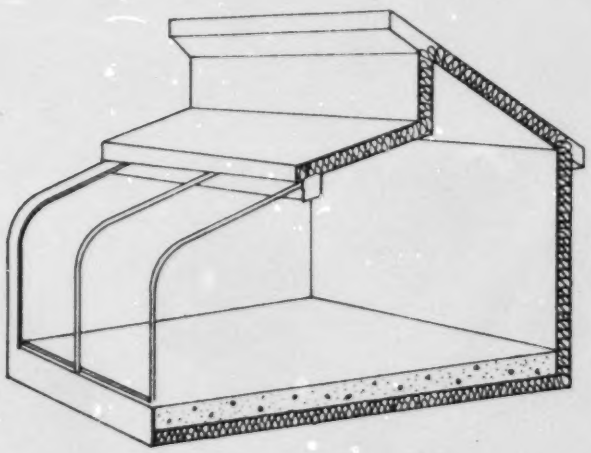


Figure 3.34

In the second mode, the Sunspace is a separate, distinct area which is thermally isolated from the living space. It is not a direct extension of the living space and its temperature can be allowed to fluctuate outside the comfort range. In this case, an auxiliary energy system is not required (see Figure 3.35).

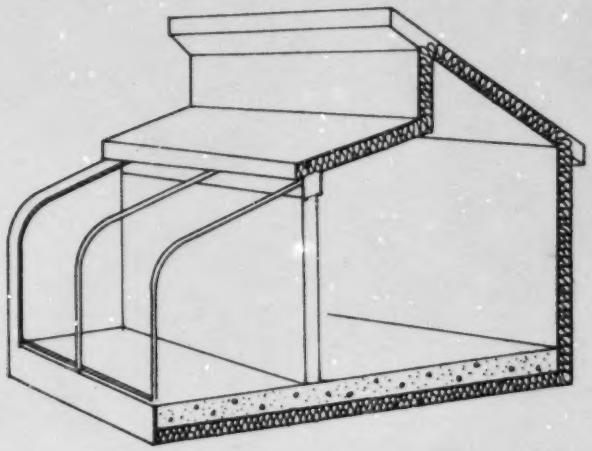


Figure 3.35

Each of the five subsystems, in its pure form, operates in one or the other of these two modes. It should be noted, however, that very often one or more systems are combined to function together. In such "hybrid" configurations, the actual mode of operation will depend on the particular subsystems involved and the way in which the space is intended to be used. This will, in turn, determine the amount and location of insulation (fixed and/or movable) employed and whether or not an auxiliary energy system is necessary.

Seasonal Operation (Heating)

During the heating season, sunlight enters an Attached Sunspace through the south facing collector (an expanse of glass or plastic), is absorbed by elements within the Sunspace, and is converted to heat. This basic process is the same for all the Attached Sunspace subsystems. It is only in the next stages of operation (storage, distribution, and control of this heat) that these subsystems differ significantly from each other. The following descriptions summarize the

operating characteristics for each of the subsystems during the heating season.

Open Wall Subsystem - In this subsystem the Sunspace opens directly to the living spaces and is basically an extension of these areas. Because of this openness there is a direct and unimpeded transfer of warm air between the two spaces. While the sun is shining, heat is generated in the Sunspace and the resulting warm air moves freely to the adjacent living spaces. Some of this heat is also stored in storage components (e.g., a masonry paver floor) located in the Sunspace and/or living spaces (see Figure 3.36).

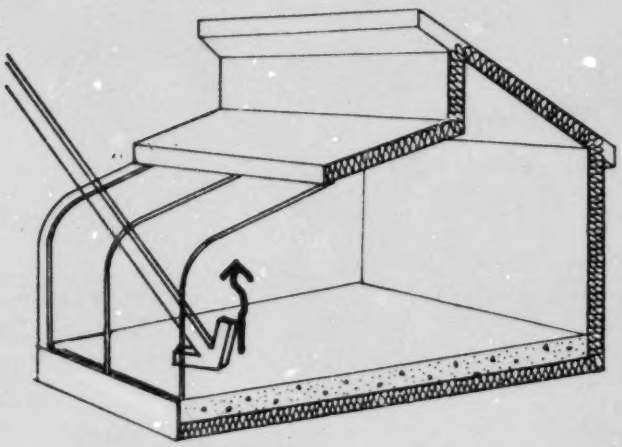


Figure 3.36

It is important to note that this subsystem, unlike the other four which follow, is essentially an extension of the living area and its temperature must be maintained at the same level as the other living spaces. The provision of storage material in the Open Wall Sunspace will help dampen temperature fluctuations, but the Sunspace in this subsystem will still need to be heated at night and during prolonged periods of cloudy weather. At these times, the direction of heat transfer is reversed and the Sunspace will receive heat from the adjacent living area as well as from the storage components located in the Sunspace itself (see Figure 3.37).

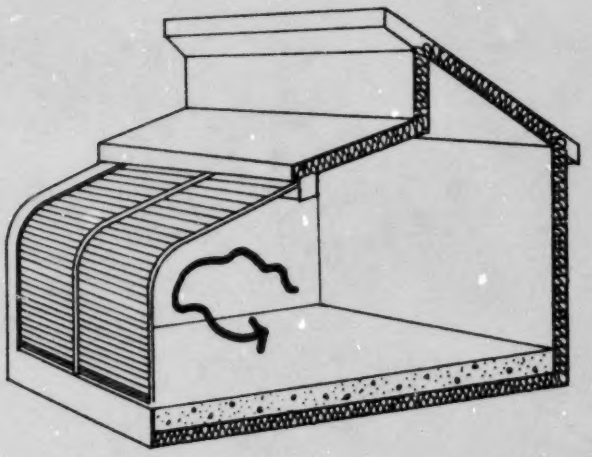


Figure 3.37

In order to avoid excessive loss of this heat, the Sunspace collector should be provided with some form of movable insulation which can be used during these periods. The Sunspace floor will also need to be insulated to the same level as the standard living space floor (see "Control" section below).

Direct Gain Subsystem - Although this subsystem is similar to the Open Wall System in construction, it is generally operated as an isolated space and is not provided with backup heating from the auxiliary energy system. The open connection between the Sunspace and the living areas is replaced by a glazed, shared wall. Because of the thermal separation which this wall provides, temperatures in the Sunspace can be allowed to fluctuate without seriously affecting the amount of heat lost from the living space. However, it may still be advisable to double glaze the shared wall in severe climates.

The use of movable insulation located at the shared wall glazing will further reduce heat losses from the living areas. This may not be cost effective, however, because the Sunspace, if properly designed, will act as a buffer between the

outside air and the living areas reducing the rate of heat loss. As a result, movable insulation will not reduce heat loss as much in this situation as it would if the living spaces were exposed directly to the outside.

Heat generated in the Sunspace can be used both to warm the Sunspace itself and to supply heat to the adjacent living areas. When providing heat only for itself, the Sunspace is acting simply as a climatic buffer for the adjacent living spaces. Some Direct Gain radiation does reach the living spaces through the glazed shared wall. However, if the glazed shared wall can be opened (e.g., patio doors), the Sunspace can provide heated air, in addition to solar radiation, to the living spaces when it is required (see Figure 3.38).

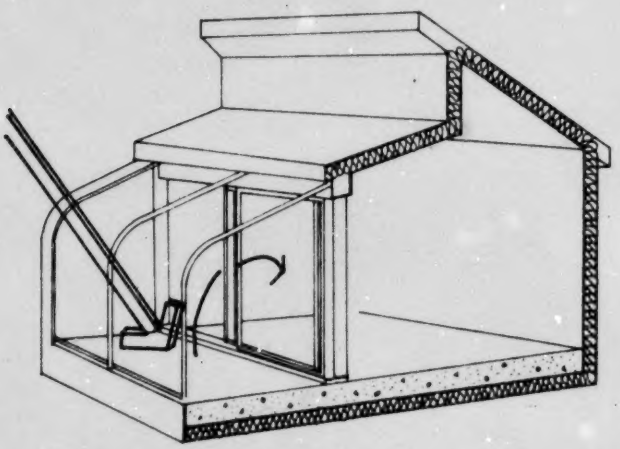


Figure 3.38

When this heat is no longer desired or when the Sunspace is no longer receiving solar radiation the homeowner can simply close the glazed wall (see Figure 3.39).

Air Exchange System - In this subsystem, the living area and the Sunspace are separated by an opaque frame wall containing operable vents. These vents allow for the transfer of heated air from the Sunspace directly to the living areas during periods of heat gain. The vents,

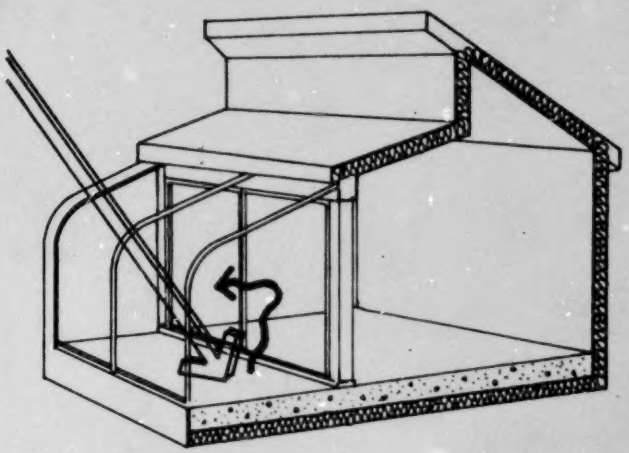


Figure 3.39

which are either manually or automatically operated, can be closed off when heat is no longer wanted or during periods of heat loss (see Figure 3.40).

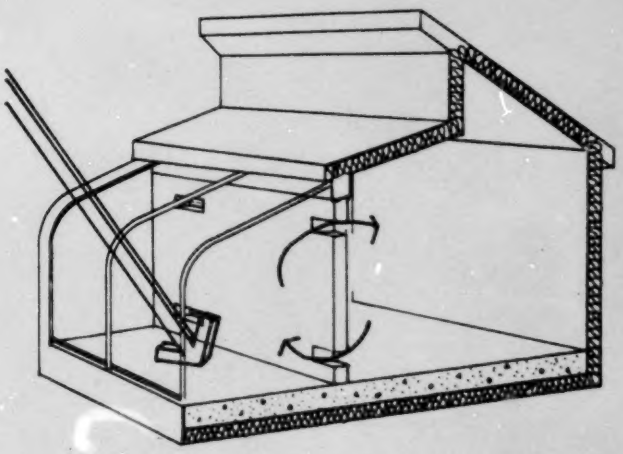


Figure 3.40

Closing the vents effectively turns the Sunspace into a buffer zone, reducing the overall heat loss from the living spaces (see Figure 3.41). Because the temperature difference is reduced, it may not be necessary to insulate this opaque shared wall. One advantage such insula-

tion might have, however, is to reduce heat gain through the wall during the cooling season, especially if the wall receives direct solar radiation during this period.

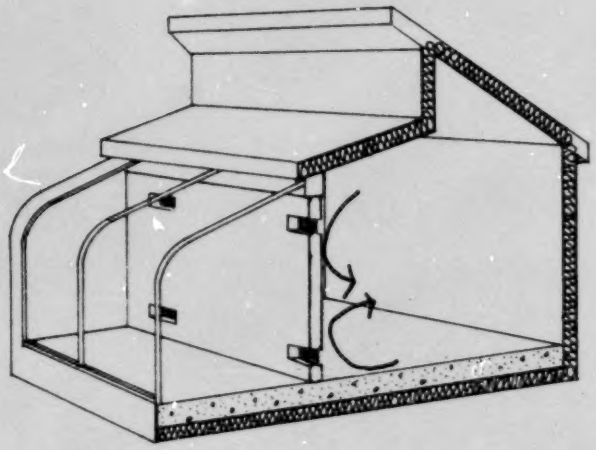


Figure 3.41

Thermal Storage Wall Subsystem - In this subsystem the shared wall between the living areas and the Sunspace is a mass wall and functions much like a standard Thermal Storage Wall. In fact, it may be easiest to visualize this subsystem as simply a Thermal Storage Wall with an enlarged airspace between the collector and storage components.

The wall absorbs incoming solar radiation and stores it. The resulting heat then slowly migrates through the wall to the adjacent living area. The wall reradiates the heat it has stored to both the living space and also back into the Sunspace itself. In doing so it not only heats the living area but also helps to maintain a relatively constant temperature in the Sunspace (see Figure 3.42).

Because this Sunspace temperature is higher than the surrounding outside air, the Sunspace acts as a thermal "buffer zone," reducing the amount of heat lost from the living space at night and during prolonged overcast periods. Movable insulation placed at the collector will

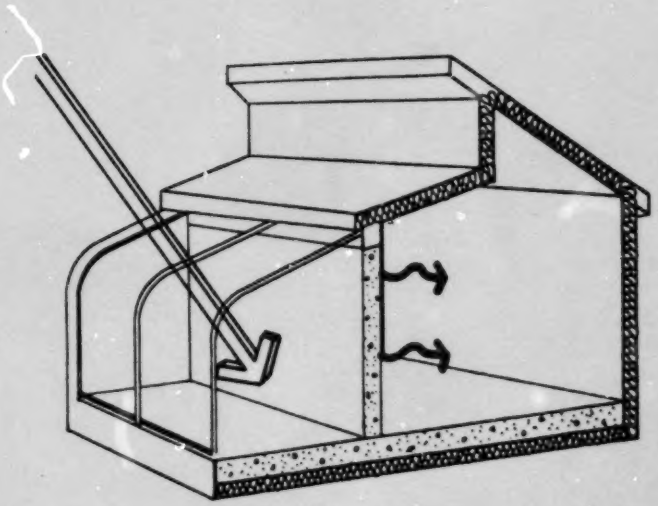


Figure 3.42

significantly improve the overall efficiency of the system. By reducing the amount of stored heat which escapes, this insulation will maintain higher temperatures in the Sunspace during the heating season. Due to these higher temperatures the shared mass wall will have less of a tendency to transfer its heat into the Sunspace and will thus provide a greater portion of its heat to the adjacent living areas (see Figure 3.43).

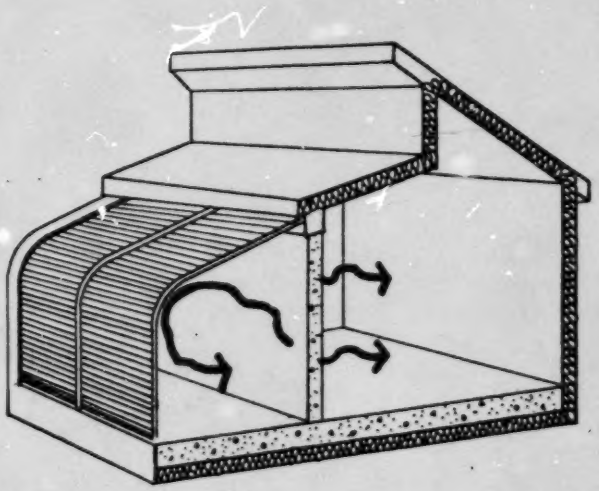


Figure 3.43

Such insulation should be located at the collector, but placement on the outside face of the shared storage wall is also possible.

It should be noted that the storage wall can also function as a vented Thermal Storage Wall. In this instance, the Sunspace is actually a "hybrid" combination of the Thermal Storage Wall and the Air Exchange Subsystems (see Figure 3.44).

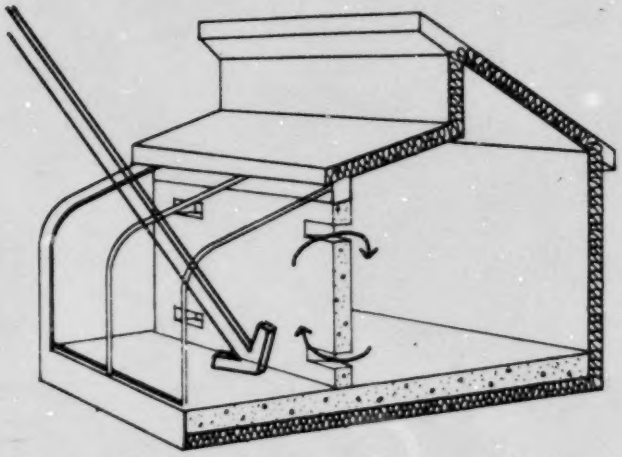


Figure 3.44

Remote Storage Subsystem - In the Remote Storage Subsystem the common wall between the living spaces and the Sunspace is opaque but is not vented, or constructed of mass materials. Its primary purpose is to thermally separate the Sunspace from the living spaces. Heat which is generated in the Sunspace is removed (usually by some form of fan system) for storage in some "remote" location away from the Sunspace and the living areas (see Figure 3.45).

The "remote storage" usually takes the form of a rock or gravel bed located under the uninsulated floor slab of the living space. Heat from the hot air blown through this gravel is stored in the rocks and then radiated up through the slab into the room to be heated. The temperature of this air is usually low

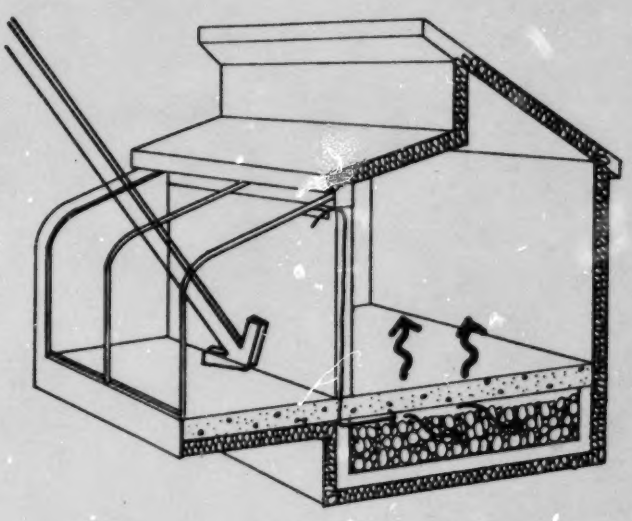


Figure 3.45

(90°F or less) and the resulting radiant heat reaching the living space will not cause the room to overheat. It might seem logical to develop a system in which the rocks are used to heat air which is in turn distributed to the rest of the home through ducts. This is not efficient, however, due to the relatively low delivery temperatures of the heat available from the storage bed (65-75°F).

Seasonal Operation (Cooling)

During the cooling season the Sunspace can easily overheat, adding to the cooling load on the auxiliary system. Therefore, the collector in any of the five subsystems should be well shaded to prevent unwanted heat gain. Deciduous trees and other types of vegetation can be used, as can building elements such as overhangs, louvers, and shades. If movable insulation has already been provided, it can serve a dual purpose and also act as a shading device.

The Sunspace should also be properly vented. If possible, low vents, to admit cool air, should be located in the shade on the windward side of the Sunspace and high vents, to exhaust hot air, on the leeward side. These vents can either be

operable glazing elements or they can form part of the opaque frame. Gable vents on the east and west endwalls are also possible. In order to reduce infiltration losses at the edges of these vents, it is preferable to have a few large vents serve the space rather than a series of smaller ones with a larger aggregate edge area (see Figure 3.46).

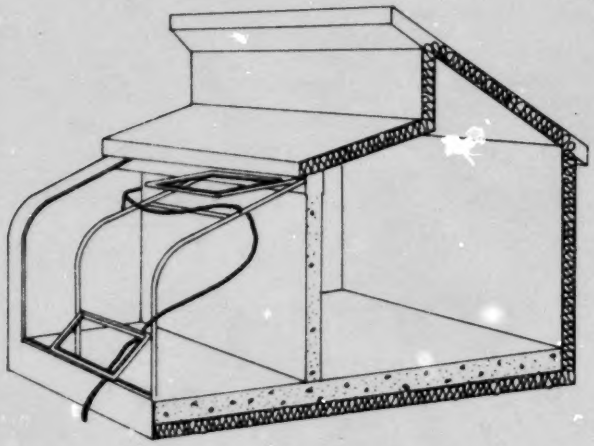


Figure 3.46

If properly managed, the storage mass within the Sunspace can also help cool it. Placing vents so as to allow cool night air to pass over the storage mass will cause it to become cooler. If properly shaded from the sun, this cooler mass will absorb heat generated in the Sunspace during the day, effectively cooling it and, depending on the subsystem involved, the adjacent living areas as well. The mass will then dissipate this collected heat to the night air, completing the diurnal cycle. Openings placed between the Sunspace and the adjacent living spaces will enhance the cooling effect of the mass by inducing cooled air to circulate through the rest of the home (see Figure 3.47).

It must be reiterated that the majority of Sunspace configurations built consist of "hybrid" combinations of the subsystems described above. It is not uncommon for a Thermal Storage Wall to include operable vents to allow for direct transfer of heated air, nor for the opaque shared wall in a Remote Storage Subsystem to include windows which allow for some Direct Gain heating in the living areas. As noted above, the thermal performance of such hybrids is, in general, very difficult to quantify. It should be assumed, however, that combining subsystems will not result in significant decreases in overall thermal performance if the general rules of thumb for Attached Sunspaces are followed.

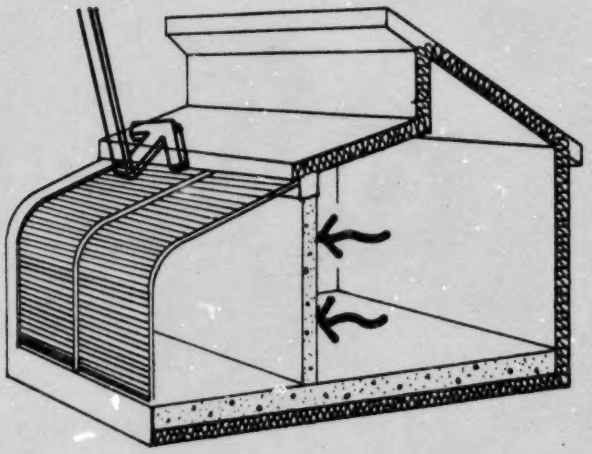


Figure 3.47

Advantages

- The Sunspace can be used for growing plants and/or food.
- The Sunspace acts as a buffer zone to reduce heat loss from the adjacent living spaces.
- The Sunspace can serve more than one function, including being an extension of the living space.
- The Sunspace can become an aesthetic asset to a house.

Disadvantages

- The thermal performance can vary significantly from one design to another and predicting performance accurately is difficult.
- Costs can be kept low by using less expensive materials, but these tend to degrade fairly quickly and the installation as a whole will be less durable. Quality construction, on the other hand, can be expensive.
- If used as a working greenhouse certain characteristics such as excess humidity, odors, control of insects, provision for running water, and drainage, must be accomodated in the design.

Collector

As in all passive solar applications, the purpose of the Attached Sunspace collector is to admit and trap solar energy. Although often perceived as a net energy loser, the large expanse of south facing glazing in a well designed Sunspace collector actually gains much more heat than it loses. The collector component functions in the same way in each of the Attached Sunspace subsystems, and the design and materials information presented below applies to all five subsystems.

There is a wide variety of possible collector configurations. A large number of Sunspaces are site-fabricated to meet specific and often idiosyncratic design specifications and the collectors for the majority of these site-built installations are framed in wood. Prefabricated, off-the-shelf collector units are usually framed in metal. Both systems have advantages and disadvantages.

The prefabricated systems are generally simple to erect, relatively impermeable to the effects of weather, and require little maintenance. They can be expensive and their dimensional modularity may inhibit design and system sizing flexibility. They may also be difficult to insulate in precisely the manner necessary to ensure maximum thermal performance. The metal frame collector system should be equipped with thermal breaks in the frame.

Site-built systems can be adapted to any particular design situation and can be insulated and shaded to meet specific conditions. Unless carefully detailed, however, such systems are notorious for failing to maintain a tight seal against the weather. Special attention must be paid to caulking and sealing the glazing material and periodic inspections should be made to ensure that the seals are still holding (see Section 4.1300 for a discussion of sealants). Rough-sawn or green wood should be avoided in such applications in favor of kiln-dried lumber. Wood should also be treated to resist moisture. Copper naphthenate should be used in greenhouse applications rather than creosote or pentachlorophenol which give off fumes that are potentially harmful to vegetation. Regardless of the material, the collector frame should be painted a light color in order to reflect more light into the Sunspace.

At present, the most common Sunspace collector material is glass and it is recommended that double glazing be used in applications where glass alone, not in combination with any other collector material, is used. For many prefabricated greenhouse manufacturers, double glazing is currently standard. In site-built applications the simplest and most common glazing type is patio door replacement glass which can be easily obtained double glazed.

Materials other than glass are, however, gaining in popularity. These include various forms of fiberglass, acrylics, polycarbonates, and certain glazing films such as polyethylene. Each of these has its own advantages and disadvantages which are discussed in detail in Section 4.1100. Each can also be used in combination with any of the other materials to maximize the best qualities of each. For example, the roof of the Sunspace might be constructed of corrugated

fiberglass because of its ease of handling during construction, while the vertical portion might be standard double glass to provide a view to the outside. Combinations and variations such as this should be considered for each individual application. The advantages of using a light-diffusing collector material to promote a balanced distribution of incoming solar energy should also be considered if storage mass is evenly distributed throughout the Sunspace.

In general, collector material on the east and west walls is thermally inefficient, losing more heat than it gains. It is recommended that such walls be opaque and well insulated where possible or, that the house itself "wrap around" the Sunspace on the east and west.

Rules of Thumb

- Orientation:
  Extend the sunspace along the south wall of the building for the most efficient performance. Orientation can be up to 20° east or west of true south without significant loss in performance. East is generally preferred to allow morning sun to "wake up" the Sunspace.

- Sloped Glazing:
  The angle of tilt for any sloped surface of the Sunspace collector should be between 45° and 60°. The tilt should be slightly flatter (nearer 45°) in overcast or foggy areas, and slightly steeper (nearer 60°) in mostly clear and sunny areas.

- End Walls:
  East and west walls of Sunspace should be opaque and well-insulated. "Wrapping" the main building around the Sunspace is a good approach.

- Sizing:
  Table 3.3 can be used to determine the collector size.

  For example, for Madison, Wisconsin, at 43°NL with an average January temperature of 21.8°F (data available from local and/or national weather bureau), select the closest "Average Winter Outdoor Temperature" (20°F). Reading across the table it is recommended that 0.9 to 1.5 square feet of glazing be used per square foot of floor area. Because Madison is at a relatively high latitude, the upper end of this range should be employed and a figure of 1.3 will be adequate. Thus to heat a living space of 200 square feet, 260 square feet of south facing glazing will be required.

Storage

The five Attached Sunspace subsystems embody unique approaches to the problem of thermal storage and each is treated separately below.

Open Wall Subsystem - In this subsystem solar radiation is absorbed by and stored in the Sunspace floor and, where applicable, the opaque endwalls, if they are made of suitable materials (see Figure 3.48).

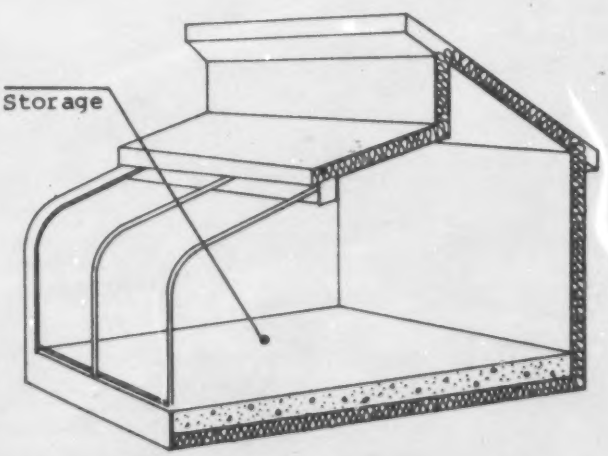


Figure 3.48

Storage elements can also be provided in the living areas and will prove very

Table 3.3

Average Winter Outdoor Temperature (Clear Day)*	Square Feet of Sunspace Glazing Needed for Each One Square Foot of Floor Area**
COLD CLIMATES	
20°F	0.90 - 1.50
25°F	0.78 - 1.30
30°F	0.65 - 1.17
TEMPERATE CLIMATES	
35°F	0.53 - 0.90
40°F	0.42 - 0.69
45°F	0.33 - 0.53

* Temperatures listed are for December and January, usually the coldest months.

** Within each range choose a ratio according to your latitude. For southern latitudes (i.e., 35°NL) use the lower glazing to floor area ratios; for northern latitudes (i.e., 48°NL), use the higher ratios. For a poorly insulated sunspace or building, always use slightly more glazing.

effective if sunlight can penetrate deeply enough into the living spaces to strike them directly. The majority of the heat reaching the living areas, however, will be in the form of warm air generated in the Sunspace during the day.

The storage components in the Sunspace and the adjacent living spaces can be made from any of a variety of high thermal storage capacity materials and should be as dark a color as possible to increase absorption of solar radiation (see Section 4.2000).

Direct Gain Subsystem - In this subsystem the storage components are the same as in the Open Wall Subsystem and function in a similar manner (see Figure 3.49).

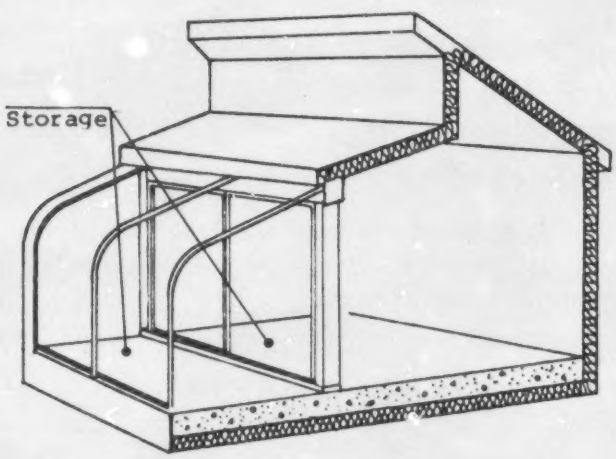


Figure 3.49

The chief difference is that the living area storage components, while still receiving direct solar radiation through the glazed shared wall, do not normally receive convected warm air from the Sunspace. The heat collected and stored in the Sunspace is only available to the living areas when the shared wall glazing is opened. At other times, when the glazing is closed, this heat is used to maintain warm temperatures in the otherwise unheated Sunspace. In this mode of operation the Sunspace serves as a buffer zone, reducing heat losses from the adjacent living areas, thereby reducing overall fuel consumption.

In this subsystem, as in the Open Wall Subsystem, the storage elements can be of the same materials and construction as those found in a Direct Gain system (see Section 3.1000).

Air Exchange Subsystem - In this subsystem the living areas are separated from the Sunspace by an opaque shared wall and receive no direct solar radiation. Vents in this wall allow warm air generated in the Sunspace to be convected into the living areas (see Figure 3.50).

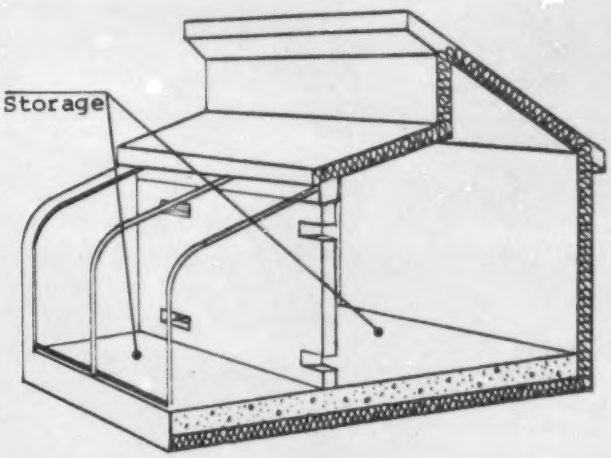


Figure 3.50

As in the other subsystems, storage mass located in the Sunspace will absorb and store heat. When heat is required in the living spaces, the wall vents are opened and warm air is allowed to flow from the Sunspace into the living areas. When the vents are closed, the stored heat is used to heat the Sunspace itself, helping it to act as a thermal buffer reducing heat losses from the adjacent living areas. Once again, the materials and construction techniques used in Direct Gain applications are appropriate for the Air Exchange Sunspace storage components (see Section 3.1000).

Thermal Storage Wall Subsystem - This subsystem acts very much like a Thermal Storage Wall with a much larger airspace between the storage wall and the collector. The mass wall separating the living areas from the Sunspace is used to absorb and store solar radiation which is in turn used to heat both the living areas and the Sunspace itself. The wall can be built of any of the Thermal Storage Wall materials covered in Section 3.2000 and will be constructed in much the same fashion (see Figure 3.51).

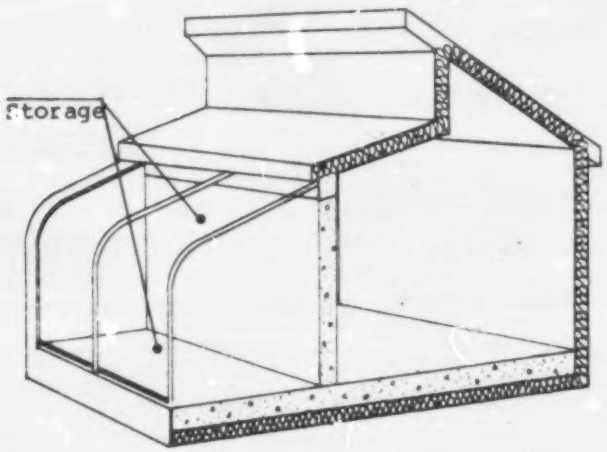


Figure 3.51

Whatever material is chosen, the Sunspace side of the wall should be painted a dark color to increase absorption of incoming solar energy (see Appendix A for the absorptivities of various materials and colors). The interior surface can be painted or left unfinished. Finishes other than paint, however, will decrease the efficiency of the wall by restricting its ability to reradiate heat. Plaster and wallpaper will have only a minor effect in this regard. Gypsum board can also be acceptable if it is attached directly to the wall (not on furring strips) and if care is taken during installation to apply a very thick coat of construction adhesive in order to increase the thermal connection between the wall and the gypsum board. Finishes which are attached to the wall with furring strips will create an insulating airspace, significantly reducing the performance of the system.

The heat radiating from the storage wall back into the Sunspace, along with heat stored in elements within the Sunspace itself, will help maintain higher than ambient temperatures in this space. As in the other subsystems, these higher temperatures will help reduce heat losses from the adjacent living spaces. As in the other subsystems, the materials and construction techniques used for Direct Gain storage components will be appropriate in the Thermal Storage Wall subsystem (see Section 3.1000).

Remote Storage System - In this subsystem, the storage is typically a "rock bed," literally a bed of rocks usually located under the floor of the major living spaces. Heat is delivered to this bed in the form of heated air from the Sunspace (see Figure 3.52).

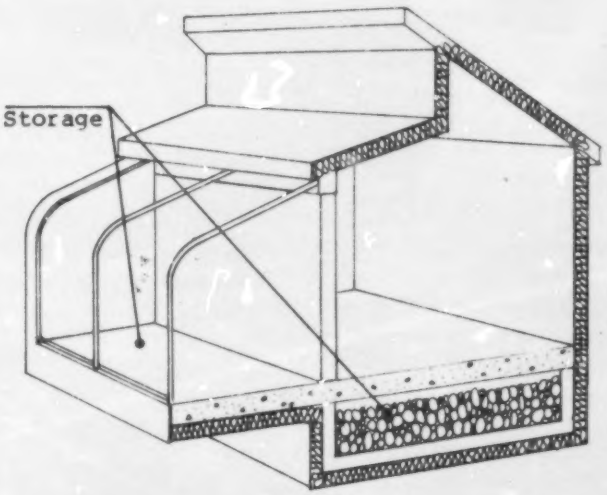


Figure 3.52

Because the temperature of this delivered heat is relatively low (90°F), it is not efficient to first store this heat in the rock bed and then circulate air from the warm bed to the living spaces. The large duct sizes and fans necessary at these low temperatures will not be cost effective. Allowing the delivered hot air to

convect up directly through openings in a frame floor can work, but it is generally better to simply allow the heat from the bed to radiate through the floor of the home. For this reason, the bed should lie under as large a portion of the living space floor as possible, and the floor should be made of a masonry material.

The masonry floor can be constructed on top of a wood floor over a crawl space, in which case the rocks should come up right under the wood subfloor, or it can simply be a slab laid directly on top of the bed.

In any rock storage system care should be taken to ensure that the heated Sunspace air is distributed evenly throughout the rock bed.

Rules of Thumb

Floors (All Subsystems)

- o Thickness:
  Standard slab thicknesses are usually appropriate. Consult Rules of Thumb in the Direct Gain section.

Walls (Thermal Storage Wall Subsystem)

- o Thickness:
  The recommended Attached Sunspace storage wall thickness: 8" - 18".

Rock Bed (Remote Storage Subsystem)

- o Area:
  1. In cold climates the bed area should be 75-100% of the floor area of the living space to be heated.
  2. In moderate climates the bed area should be 50-75% of the floor area of the living space to be heated.

- o Volume of Rock Bed:
  1. 3/4 - 1 1/2 cubic feet of fist-sized (2"-3" diameter) rocks* per square foot of Sunspace glazing (severe climates).
  2. 1 1/2 - 3 cubic feet of fist-sized (2"-3" diameter) rocks* per square foot of Sunspace glazing (moderate climates).

  * The smaller rock or gravel sizes can be more efficient due to the greater amount of surface area available for heat transfer. General rule: bed depth in the direction of air flow = 20 x diameter of rocks.

Vents (Air Exchange Subsystem)

- o Size:
  Interior vents should be a minimum of 3% of the area of the shared wall between the Sunspace and the adjacent living spaces. To achieve a more balanced air flow upper vents should not be located directly over lower vents, but should be moved to one side if possible. Backdraft dampers or operable louvers should be provided for upper vents to prevent reverse thermocirculation.

Control

Shading

In each of the Attached Sunspace subsystems it is recommended that some method for shading the collector be provided to help avoid unwanted summer heat gain. Most of the devices used in Direct Gain are applicable for at least the vertical or near vertical wall section of the collector, including: vegetation (trees), trellises, vertical and/or horizontal louvers and attached awnings.

The glazed portion of the collector roof, however, represents a slightly different shading condition. The most efficient way to shade this area is to use operable wood, aluminum or plastic roller shades attached directly to the collector, preferably on the outside. Prefabricated collectors are often equipped with these shades integrated into the framing system. In site-built installations provision should be made for the inclusion of such elements as part of the site-built frame.

Introduction

Wherever possible, it is recommended that the roof portion of the collector be opaque at its connection to the home. This opaque roof will serve as an overhang for shading the Sunspace. In working greenhouse applications care should be taken to balance the amount of shading with the daylight requirements of the plants (see Figure 3.53).

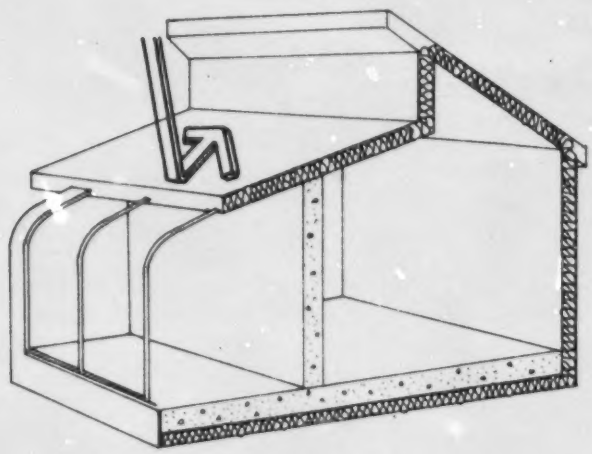


Figure 3.53

Reflecting

Reflecting panels can be used in any of the Attached Sunspace subsystems to enhance the amount of solar energy reaching the collector. They should be located so as to reflect sunlight onto the mass within the space without directing excessive radiation directly onto the plants.

Insulating (Fixed Exterior Insulation)

In general all exposed opaque surfaces in the Sunspace, including roof and endwalls, should be well insulated to reduce heat flow to the exterior. Standard insulating techniques are appropriate except in the case where a particular construction is intended to function as a storage component. For example, if an endwall in the Sunspace is to function as a Direct Gain storage component, the construction procedures and insulation techniques should follow the discussions and details in Section 3.1000.

Foundation insulation will, of course, reduce heat losses. These reductions can be increased if the floor slab is also insulated at its perimeter. However, such perimeter insulation may or may not be advisable, depending upon the particular mode in which the Sunspace is operated.

If the Sunspace is thermally isolated from the living area and its temperatures are allowed to fluctuate freely, perimeter insulation will not be necessary if foundation insulation is already provided. If the Sunspace is not thermally isolated from the living space and/or if an auxiliary energy system is used to maintain temperatures in the Sunspace within the comfort range, some insulation under the slab should be provided in addition to foundation insulation. Perimeter insulation is adequate, but insulating under the entire slab may be more effective. In general, the floor in such Sunspaces should be insulated to the same extent as a Direct Gain floor would be in the same location (see Storage Rules of Thumb, Section 3.1000).

In general, it is not necessary to provide fixed insulation for the shared wall between the Sunspace and the adjacent living spaces in any of the five subsystems. In the Open Wall and Direct Gain Subsystems such considerations do not apply. In the Air Exchange and Remote Storage Subsystems, the shared wall need not be insulated because movable insulation is already provided at the collector. In the Thermal Storage Wall Subsystem insulating the shared storage wall will effectively nullify any passive benefits which the wall might provide.

Insulating (Movable Insulation)

The provision of movable insulation at

the Sunspace collector is recommended for all five subsystems. Such insulation will reduce heat losses during prolonged overcast periods and at night, as well as prevent unwanted heat gain during the cooling season. This will generally result in significant increases in the thermal performance of all of the subsystems. In fact, in more severe climates, certain Attached Sunspace configurations may be net energy losers if such insulation is not provided.

Most movable insulation for Attached Sunspace collectors will not be available off-the-shelf, but will need to be adapted from existing types commonly used in Direct Gain or Thermal Storage Wall applications. The most appropriate shades will be rigid panels (exterior or interior) or some form of insulating shade (either attached to the glazing frame or suspended from wires within the Sunspace).

These insulating materials may be bulky and difficult to store, if not designed into the collector framing system. Manual operation of movable insulation is often very simple but requires an active commitment on the part of the homeowners. It is therefore recommended that automatic systems, either switch or thermostatically controlled, be considered.

No matter what system is used, care must taken to ensure a tight fit between insulation and the collector to avoid infiltration losses. Local codes should also be consulted to assess the eligibility of certain materials for use in exposed situations. For example, some insulating materials such as polystyrene and urethane may be considered health or fire hazards.

Rules of Thumb

Shading

- Overhangs:
  The projection of the overhang that will be adequate (provide 100% shading at noon on June 21) at particular latitudes can be quickly calculated by using the following formula:

$$\text{Projection} = \frac{\text{window opening (height)}}{\text{F (see table below)}}$$

North Latitude	F Factor*
28°	5.6-11.1
32°	4.0- 6.3
36°	3.0- 4.5
40°	2.5- 3.4
44°	2.0- 2.7
48°	1.7- 2.2
52°	1.5- 1.8
56°	1.3- 1.5

* Select a factor according to the latitude. The higher values will provide 100% shading at noon on June 21, the lower values until August 1.

A slightly longer overhang may be desirable at latitudes where this formula does not provide enough shade during the latter part of the cooling season (see Figure 3.15).

For example, for Madison, Wisconsin, at 43°NL, select an F factor between 2.0 and 2.7 (values for 44°NL). Assuming shade is desired until August 1, choose the lower value of 2.0. If the collector height (h) is 8 feet, the projection (l) of the overhang placed at the top of the collector will be: $\frac{8}{2.0} = 4$ feet.

Reflecting

- Sizing:
  The reflector should be the same length as the collector area served and roughly twice as wide as the collector area is high.

- Slope:
  A downward slope (away from collector) of roughly 5° is recommended.

Insulating

- Fixed Insulation:
  Fixed exterior insulation R-values should meet or exceed the levels that would be maintained by the same element in a non-solar building, which should in turn meet or exceed local building code requirements.

- Movable Insulation:
  Movable insulation should have an R-value between R-4 and R-9, subject to cost-benefit considerations.

- Seal:
  All insulation should provide a tight seal to avoid heat loss at its edges.

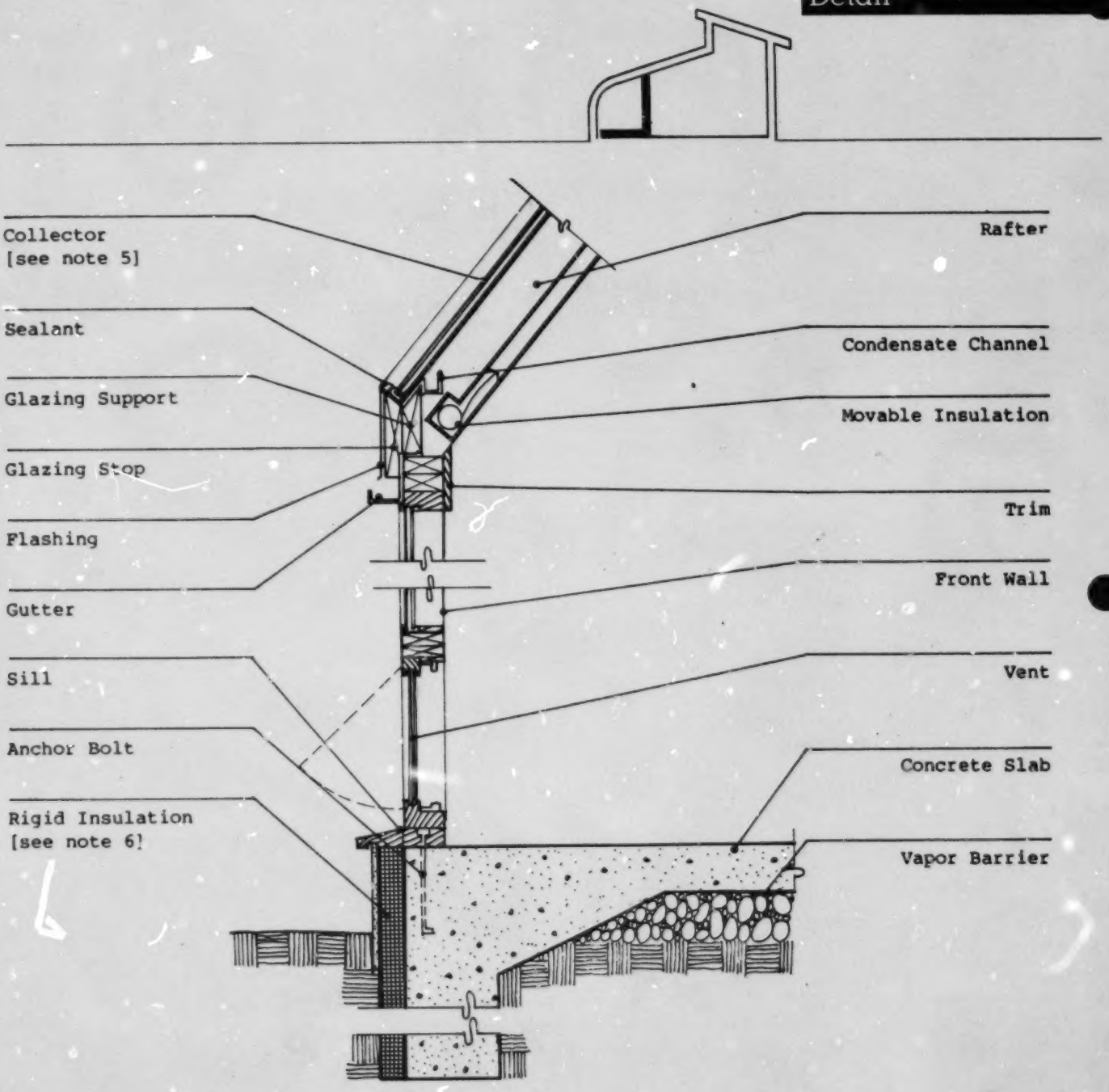
Vents (Exterior)

- Area:
  The exterior vent area should be 1/6 of the area of the wall covered by the Sunspace. The top vents should be 1/3 larger than bottom vents. The vertical distance between vents should be as great as possible.

Attached Sunspace
Site-Built Collector
Glazed Front Wall

3.3210

Detail



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Construction Notes

[1] All footings must bear on undisturbed soil. Adjust footing size, reinforcing and depth below grade as required by site conditions and/or local code.

[2] Insulation levels must meet or exceed local building/energy code requirements for foundation insulation.

[3] High humidity levels in Attached Sunspaces used as working greenhouses may necessitate treating wood framing members with preservative. Avoid preservatives harmful to plants.

[4] Provide adequate drainage in Attached Sunspace floor, particularly where extensive planting is planned.

[5] A variety of materials can be specified for the collector glazing. For further material information see Section 4.1100.

[6] Cement plaster (stucco) finish applied on wire lath over exterior insulation. Other finish may be specified at builder's option, but rigid insulation must be protected where exposed above grade. Consult insulation manufacturer for recommended installation procedures.

[7] Sizing of framing members to be determined by weight of glazing material, loading requirements, and desired clear spans. All structural elements must be designed to meet local building codes and/or accepted practice.

[8] Movable insulation should be provided to improve thermal performance. For further information see Section 3.3000.

[9] Condensate channel formed by turning up metal flashing.

[10] Structure and height of Attached Sunspace front wall may vary depending upon design and use. Wall may be glazed or insulated opaque frame wall.

[11] Operable glazed unit serves as vent during the cooling season. For further information, see Key Pages 3.3100 through 3.3106.

[12] Concrete slab-on-grade used as Storage component in Attached Sunspace. Alternate Storage floor materials may be specified at builder's option. For further information, including recommended construction techniques, see Key Page 3.1170 and following.

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UNIT VII
PASSIVE SOLAR FUNDAMENTALS

COMPETENCY 5: Understanding the convective loop

LEARNING STEPS:

1. Define convective loop
2. Determine the major components of convective loop
3. Determine how the convective loop functions.

LEARNING ACTIVITIES:

1. Attend teacher presentation on the convective loop.
2. Read Information Sheet VII-5-1 "Passive Solar Fundamentals-Convective Loop".
3. Define collector, absorber, storage, convection, and reverse loop.
4. Read "Double-Shell Solar House" by Ron Dans, Popular Science, Dec, 1979, pp 54-57, 116-117 Vol. 215, No. 6

EVALUATION:

In your own words, explain how the convective loop works.

The Convective Loop is primarily a heating type system most appropriate in areas experiencing moderate to severe winters. It is based on the principle that a fluid, such as air, will rise when heated.

During the heating season, the Convective Loop collector admits sunlight which in turn strikes an absorber surface and is converted to heat. This heat is transmitted to the air in the space between the absorber surface and the collector. As the heat is collected at the lowest point in the system, the heated air rises up, passing out through a duct located at the top of the absorber, to be replaced by cooler return air drawn in from below. This warm air can be dumped directly into the living spaces or it can be diverted into a remote storage area, such as a rock bed, and used to provide heat as required (see Figure 2.16).

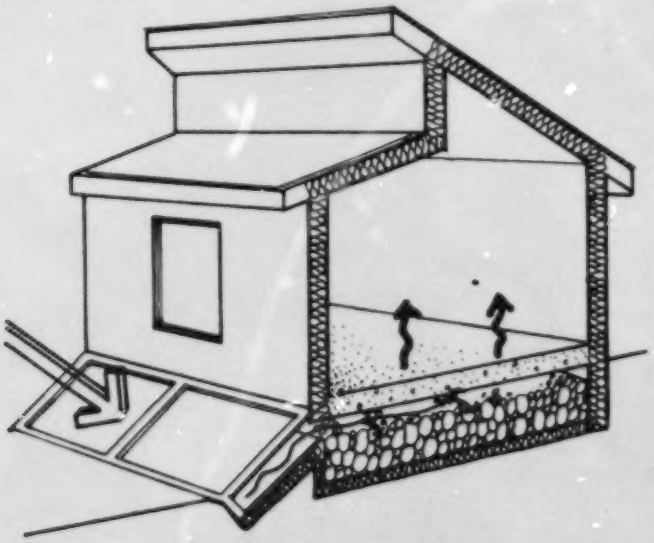

Figure 2.16

The major control component required by this system is some method for preventing the loop from reversing itself at night or during prolonged cloudy periods, drawing heated air out of storage. Simple backdraft or automatic thermostatically controlled dampers can be used to prevent this back flow. If such controls are provided it will not be necessary to insulate or shade the collector during the heating season.

It may be desirable to provide some form of reflector to enhance the amount of solar radiation striking the collector. Such reflectors are particularly appropriate for a Convective Loop because the system is thermally isolated, and often physically separated, from the living spaces. Common reflector problems associated with excessive radiation and glare in the living spaces are thus avoided.

During the cooling season the collector should be well shaded (see Figure 2.17) or covered to prevent possible damage to

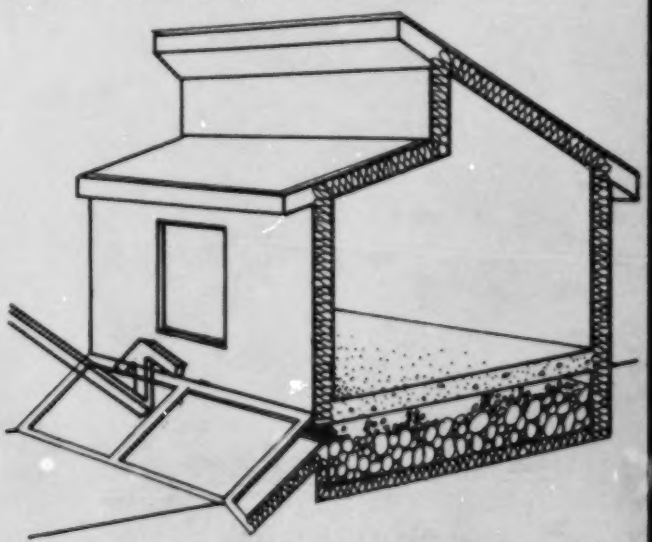

Figure 2.17

the absorber surface as a result of excessive heat build-up in the system.

Typically a Convective Loop system is constructed directly on the south wall of a home, or is a separate structure placed slightly in front of and below the first floor. In either configuration heat flow is by natural means. No fans or pumps are required, which constitutes a chief difference between this and typical active hot air systems.

UNIT VIII
MAINTENANCE

COMPETENCY 1: Maintain an Energy-Efficient Home

LEARNING STEPS:

1. Identify areas of the home that require maintenance.
2. Determine how often maintenance is required.
3. Learn procedures and materials needed for maintenance.

LEARNING ACTIVITIES:

1. Attend instructor's lecture on home maintenance.
2. Read Information Sheet VIII-1-1 "Maintaining an Energy-Efficient Home".
3. List some energy saving measures that can be performed periodically by the home owner.

EVALVATION:

Make up a maintenance schedule in the form of a checklist to be followed in maintaining an energy efficient home.

Maintaining an Energy-Efficient Home

The key to year 'round comfort is a home kept in good condition. Energy bills and maintenance costs will be much lower if a home is checked both in the fall and spring. During these seasons you can open doors and windows without heat loss or gain and service heating and cooling systems which are not being operated. Outdoor repairs are also easier at these times of the year. Lists are given under the following headings:

1. Fall Check List.
2. Spring Check List.

1. FALL CHECK LIST

1. Check insulation wherever possible—unfinished crawl spaces or attics.

   Check thickness and condition. Damp insulation should lead you to discover the source of the problem. Make necessary improvements.

2. Look closely at weatherstripping and caulking around all windows and doors.

   Repair cracked or separated caulking and replace worn-out weatherstripping.

3. Clean and repair windows.

   Check weatherstripping and make sure windows operate easily. Check caulking around storms. Store screens to give maximum light for the winter.

4. Cover exterior portion of your air conditioner unit with a weatherproof sleeve during the winter.

5. Clean all gutters and drain pipes.

6. Service heating systems and heat pumps.

   Change filters, vacuum ducts and registers or radiators, and have service person do annual maintenance on burner units. Have chimneys cleaned.

7. Drain a few pails of water from the hot water heater to remove sediment.

   Extensive draining to clear the water may suggest rust problems or other deterioration.

8. Check and clean burner units on hot water heaters.

9. Replace washers on leaky faucets.

10. Check caulking around outside faucets and drain them so that the water won't freeze.

11. Check roofs for leaks.

    Use unfinished attic and/or damp insulation as a way to detect leaks. Replace any damaged tiles or roofing materials. With a finished attic, you can check from the outside.

12. Clean all lighting fixtures.

13. Check house siding for holes or cracks.

    Fill with caulking.

14. Check and clean your humidifier as recommended by the manufacturer's instructions.

15. Check fireplace damper to make sure it closes tightly.

    Have chimney cleaned.

16. Check insulation on pipes passing through unheated areas.

17. Store canvas awnings to prevent unnecessary wear.

18. Clean refrigerator and freezer coils.

19. Determine if off-peak-hour use of electricity is on proper schedule.

2. SPRING CHECK LIST

1. Check for winter damage to windows and doors.

   Caulk, weatherstrip and refinish if necessary. Check and replace screens. Store storms.

2. Check attic for any ventilation problems.

   Clean the attic to control dust and dirt circulation. Clean vents if necessary and check for insect nests. Power vents should be cleaned according to manufacturer's instructions.

3. Check outside of house for cracks, peeling paint and other damage.

   Schedule necessary painting.

4. Clean drapes and blinds and make sure they are in good working condition.

5. Reinstall summer awnings.

   Check and repair.

6. Remove winter cover from air conditioner.

   Clean or replace filter.

7. Switch off pilot light for gas or oil heat.

   Have service person do this if remote switch is not in use.

8. Clean dryer vent.

   Install one if this has not been done.

9. Check off-peak-hour schedule for use of electricity.

10. Check and clean stove hood and room fans.

11. Turn thermostats on heating systems to lowest position or "off" position.

12. Check seals on refrigerators and freezers and clean refrigerator coils.

13. Clean fireplace.

    With a screened chimney, the damper may be left open for better ventilation.

14. Check landscaping to determine if additional planting of shrubs or trees will help for shade or as a wind barrier.

15. Check basement.

    If basement is damp or moisture shows on walls, remedy the situation with a dehumidifier or special paint.

16. Put dehumidifier into service by cleaning according to manufacturer instructions.

17. Check plumbing and make repairs.

APPENDIX I

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TABLE I. APPPOXIMATE THICKNESS OF INSULATION FOR THERMAL RESIDENCES, IN.
(Reference, Cooling and Heating Load Calculation Manual,
ASHRAE, 1979, Table 7.5, Page 7.21)

Thermal Resistance of Insulation	Batts or Blankets		Loose Fill			Boards and Slabs	
	Glass Fiber	Rock Wool	Glass Fiber	Rock Wool	Celluiosic	Polyurethane	Cellular Glass
R-7	2 1/4 to 2 3/4	2	3 to 4	2 to 3	2	1	2 5/8
R-11	3 1/2 to 4	3	5	4	3	1 3/4	4 1/4
R-13	3 5/8	3 1/2	6	4 to 5	4	2	5
R-19	6 to 6 1/2	5 1/4	8 to 9	6 to 7	5	3	7 1/4
R-22	6 1/2	6	10	7 to 8	6 ·	3 1/2	8 3/8
R-30	9 1/2 to 10 1/2	9	13 to 14	10 to 11	8	4 3/4	11 3/8
R-38	12 to 13	10 1/2	17 to 18	13 to 14	10 to 11	6	14 1/2

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TABLE II. OUTSIDE DESIGN TEMPERATURES AND HEATING DEGREE-DAYS (65°F BASE) FOR DIFFERENT CLIMATIC LOCATIONS
(Adapted from Cooling and Heating Load Calculation Manual, ASHRAE, 1979, Pages 2.3 and 7.16)

State and Station	Winter Design Dry-Bulb		Summer Design Dry-Bulb and Mean Coincident Wet-Bulb			Mean Daily Range	Heating Degree Days
	99%	97.5%	1%	2.5%	5%		
ALABAMA							
Huntsville AP	11	16	95/75	92/74	91/74	23	3,070
Mobile AP	25	29	95/77	93/77	91/76	18	1,560
ALASKA							
Fairbanks AP (S)	-51	-47	82/62	78/60	75/59	24	14,279
Kodiak	10	13	69/58	65/56	62/55	10	
ARIZONA							
Flagstaff AP	- 2	4	84/55	82/55	80/54	31	7,152
Phoenix AP (S)	31	34	109/71	107/71	105/71	27	1,765
ARKANSAS							
Fayetteville AP	7	12	97/72	94/73	92/73	23	
Little Rock AP (S)	15	20	99/76	96/77	94/77	22	3,219
CALIFORNIA							
Los Angeles AP (S)	41	43	83/68	80/68	77/67	15	2,061
San Francisco AP	35	38	82/64	77/63	73/62	20	3,001
COLORADO							
Denver AP	- 5	1	93/59	91/59	89/59	28	6,283
Leadville	-18	-14	84/52	81/51	78/50	30	
CONNECTICUT							
Bridgport AP	6	9	86/73	84/71	81/70	18	5,617
Waterbury	- 4	2	88/73	85/71	82/70	21	
DELEWARE							
Dover AFB	11	15	92/75	90/75	87/74	18	
Wilmington AP	10	14	92/74	89/74	87/73	20	4,930
D.C.							
Andrews AFB	10	14	92/75	90/74	87/73	18	4,224
Wash Nat AP	14	17	93/75	91/74	89/74	18	

TABLE II (Continued)

State and Station	Winter Design Dry-Bulb 99%	Winter Design Dry-Bulb 97.5%	Summer Design Dry-Bulb and Mean Coincident Wet-Bulb 1%	Summer Design Dry-Bulb and Mean Coincident Wet-Bulb 2.5%	Summer Design Dry-Bulb and Mean Coincident Wet-Bulb 5%	Mean Daily Range	Heating Degree Days
FLORIDA							
Gainesville AP	28	31	95/77	93/77	92/77	18	
Miami AP (S)	44	47	91/77	90/77	89/77	15	214
Tallahassee							1,485
GEORGIA							
Atlanta AP (S)	17	22	94/74	92/74	90/73	19	2,961
Waycross	26	29	96/77	94/77	91/76	20	
Thomasville							1,529
HAWAII							
Honolulu AP	62	63	87/73	86/73	85/72	12	
Wahiawa	58	59	86/73	85/72	84/72	14	
IDAHO							
Boise AP (S)	3	10	96/65	94/64	91/64	31	5,809
Idaho Falls AP	-11	- 6	89/61	87/61	84/59	38	
ILLINOIS							
Carbondale	2	7	95/77	93/77	90/76	21	
Chicago, O'Hare AP	- 8	- 4	91/74	89/74	86/72	20	6,639
INDIANA							
Fort Wayne AP	- 4	1	92/73	89/72	87/72	24	6,205
Indianapolis AP (S)	- 2	2	92/74	90/74	87/73	22	5,699
IOWA							
Des Moines AP	-10	- 5	94/75	91/74	88/73	23	6,588
Waterloo	-15	-10	91/76	89/75	86/74	23	7,320
KANSAS							
Manhattan, Fort Riley (S)	- 1	3	99/75	95/75	92/74	24	
Wichita AP	3	7	101/72	98/73	96/73	23	4,660
KENTUCKY							
Lexington AP	3	8	93/73	91/73	88/72	22	4,683
Louisville AP	5	10	95/74	93/74	90/74	23	4,660
LOUISIANA							
Natchitoches	22	26	97/77	95/77	93/77	20	
New Orleans	29	33	93/78	92/78	90/77	16	1,385

Table II (Continued)

State and Station	Winter Design Dry-Bulb 99%	Winter Design Dry-Bulb 97.5%	Summer Design Dry-Bulb and Mean Coincident Wet-Bulb 1%	Summer Design Dry-Bulb and Mean Coincident Wet-Bulb 2.5%	Summer Design Dry-Bulb and Mean Coincident Wet-Bulb 5%	Mean Daily Range	Heating Degree Days
MAINE							
Caribou AP (S)	-18	-13	84/69	81/67	78/66	21	9,767
Lewiston	-7	- 2	88/73	85/70	82/68	22	
MARYLAND							
Baltimore CO	14	17	92/77	89/76	87/75	17	4,111
Frederick	8	12	94/76	91/75	88/74	22	
MASSACHUSETTS							
Boston AP (S)	6	9	91/73	88/71	85/70	16	5,634
Springfield, Westover AFB	- 5	0	90/72	87/71	84/69	19	
MICHIGAN							
Detroit	3	6	91/73	88/72	86/71	20	6,232
Sault Ste. Marie AP (S)	-12	- 8	84/70	81/69	77/66	23	9,048
MINNESOTA							
Intn'l Falls AP	-29	-25	85/68	83/68	80/66	26	
Minneapolis, St. Paul AP	-16	-12	92/75	89/73	86/71	22	8,382
MISSISSIPPI							
Biloxi, Keesler AFB	28	31	94/79	92/79	90/78	16	
Tupelo	14	19	96/77	94/77	92/76	22	2,041
MISSOURI							
Kansas City AP	2	6	99/75	96/74	93/74	20	4,711
St. Louis AP	2	6	97/75	94/75	91/74	21	4,900
MONTANA							
Bozeman	-20	-14	90/61	87/60	84/59	32	
Missoula AP	-13	- 6	92/62	88/61	85/60	36	8,125
NEBRASKA							
Lincoln CO (S)	- 5	- 2	99/75	95/74	92/74	24	5,864
Omaha AP	- 8	- 3	94/76	91/75	88/74	22	6,612
NEVADA							
Las Vegas AP(S)	25	28	108/66	106/65	104/65	30	2,709
Reno AP (S)	5	10	95/61	92/60	90/59	45	6,332

Table II (Continued)

State and Station	Winter Design Dry-Bulb 99%	Winter Design Dry-Bulb 97.5%	Summer Design Dry-Bulb and Mean Coincident Wet-Bulb 1%	Summer Design Dry-Bulb and Mean Coincident Wet-Bulb 2.5%	Summer Design Dry-Bulb and Mean Coincident Wet-Bulb 5%	Mean Daily Range	Heating Degree Days
NEW HAMPSHIRE							
Keene	-12	- 7	90/72	87/70	83/69	24	7,383
Portsmouth, Pease AFB	- 2	2	90/73	85/71	83/70	22	
NEW JERSEY							4,500
NEW MEXICO							
Albuquerque AP(S)	12	16	96/61	94/61	92/61	27	4,348
Raton AP	- 4	1	91/60	89/60	87/60	34	6,228
NEW YORK							
NYC-Kennedy AP	12	15	90/73	87/72	84/71	16	5,219
Utica	-12	- 6	88/73	85/71	82/70	22	
NORTH CAROLINA							
Asheville AP	10	14	89/73	87/72	85/71	21	4,042
Raleigh/ Durham AP (S)	16	20	94/75	92/75	90/75	20	3,393
NORTH DAKOTA							9,000
OHIO							
Cincinnati CO	1	6	92/73	90/72	88/72	21	4,410
Cleveland AP (S)	1	5	91/73	88/72	86/71	22	6,351
OKLAHOMA							
Lawton AP	12	16	101/74	99/74	96/74	24	
Oklahoma City AP (S)	9	13	100/74	97/74	95/73	23	3,725
OREGON							
Pendleton AP	- 2	5	97/65	93/64	90/62	29	5,127
Portland AP	17	23	89/68	85/67	81/65	23	4,635
PENNSYLVANIA							
Philadelphia AP	10	14	93/75	90/74	87/72	21	5,144
Pittsburgh AP	1	5	89/72	86/71	84/70	22	5,987
RHODE ISLAND							
Newport (S)	5	9	88/73	85/72	82/70	16	
Providence AP	5	9	89/73	86/72	83/70	19	5,954

Table II (Continued)

State and Station	Winter Design Dry-Bulb 99%	Winter Design Dry-Bulb 97.5%	Summer Design Dry-Bulb and Mean Coincident Wet-Bulb 1%	Summer Design Dry-Bulb and Mean Coincident Wet-Bulb 2.5%	Summer Design Dry-Bulb and Mean Coincident Wet-Bulb 5%	Mean Daily Range	Heating Degree Days
SOUTH CAROLINA							
Greenville AP	18	22	93/74	91/74	89/74	21	2,980
Spartanburg AP	18	22	93/74	91/74	89/74	20	
SOUTH DAKOTA							
Brookings	-17	-13	95/73	92/72	89/71	25	
Rapid City AP (S)	-11	- 7	95/66	92/65	89/65	28	7,345
TENNESSEE							
Knoxville AP	13	19	94/74	92/73	90/73	21	3,494
Memphis AP	13	18	98/77	95/76	93/76	21	3,232
TEXAS							
Amarillo AP	6	11	98/67	95/67	93/67	26	3,985
Dallas AP	18	22	102/75	100/75	97/75	20	2,363
Houston CO	28	33	97/77	95/77	93/77	18	1,278
UTAH							
Logan	- 3	2	93/62	91/61	88/60	33	
Salt Lake City AP (s)	3	8	97/62	96/62	92/61	32	6,052
VERMONT							
Barre	-16	-11	84/71	81/69	78/68	23	
Burlington AP (S)	-12	- 7	88/72	85/70	82/69	23	8,269
VIRGINIA							
Norfolk AP	20	22	93/77	91/76	89/76	18	3,421
Roanoke AP	12	16	93/72	91/72	88/71	23	4,150
WASHINGTON							
Seattle-Tacoma AP (S)	21	26	84/65	80/64	76/62	22	5,145
Spokane AP (S)	- 6	2	93/64	90/63	87/62	28	6,655
WEST VIRGINIA							
Morgantown AP	4	8	90/74	87/73	85/73	22	4,500
Wheeling	1	5	89/72	86/71	84/70	21	
WISCONSIN							
Ashland	-21	-2[illegible]	85/70	82/68	79/66	23	7,635
Milwaukee AP	- 8	- 4	90/74	87/73	84/71	21	
WYOMING							
Cheyenne AP	- 9	- 1	89/58	86/58	84/57	30	7,381
Laramie AP (S)	-14	- 6	84/56	81/56	79/55	28	

TABLE III. CONDUCTIVITY OF SOME BUILDING MATERIALS
(Adapted from Cooling and Heating Load Calculation Manual, ASHRAE, 1979, Page 3.4)

	Conductivity (k)
Hardboard, Medium Density	.73
Particleboard, Medium Density	.94
Polystyrene, Smooth Skin	.20
Glass Fiber, Organic Bonded	.25
Wood, Medium Density	1.49

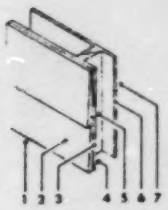
TABLE IV. CONDUCTANCE OF SOME BUILDING MATERIALS
(Adapted from Cooling and Heating Load Calculation Manual, ASHRAE, 1979, Page 3.4)

	Thickness (in)	Conductance (C)
Plywood	.5	1.60
Carpet and Fiberous Pad	-	.48
Mineral Fiber	3.5	.053
Concrete Block, Sand and Gravel	8	.90
Asphalt Shingle		2.27

TABLE V. COEFFICIENTS OF HEAT TRANSFER (U) THROUGH FRAME WALLS*

*(Reference, Cooling and Heating Load Calculation Manual, ASHRAE, 1979, Table 3.2A, Page 3.8)

These U-coefficients are expressed in Btu per (hour) (square foot) (degree Fahrenheit difference in temperature between the air on the two sides), and are based on an outside wind velocity of 15 mph. The Heat Capacity Units are Btu/ft²·F



Replace Air Space with 3.5-in. R-11 Blanket Insulation (New Item 4)

Construction	1 Resistance (R) Between Framing	1 Resistance (R) At Framing	2 Resistance (R) Between Framing	2 Resistance (R) At Framing	1 Heat Capacity Between Framing	2 Heat Capacity Between Framing
1. Outside surface (15 mph wind)	0.17	0.17	0.17	0.17	—	—
2. Siding, wood, 0.5 in.× 8 in. lapped (average)	0.81	0.81	0.81	0.81	0.47	0.47
3. Sheathing, 0.5-in. asphalt impregnated	1.32	1.32	1.32	1.32	0.23	0.23
4. Nonreflective air space, 3.5 in. (50 Fmean; 10 deg F temperature difference)	1.01	—	11.00	—	—	.08
5. Nominal 2-in. × 4-in. wood stud	—	4.38	—	4.38	—	—
6. Gypsum wallboard, 0.5 in.	0.45	0.45	0.45	0.45	0.54	0.54
7. Inside surface (still air)	0.68	0.68	0.68	0.68		
Total Thermal Resistance (R)	R_i=4.44	R_s=7.81	R_i=14.43	R_s=7.81	1.24	1.32

Construction No. 1: U_i = 1/4.44=0.225; U_s=1/7.81 =0.128. With 20% framing (typical of 2-in. × 4-in. studs @ 16-in. o.c.), U_{av} = 0.8 (0.225) + 0.2 (0.128) = 0.206 (See Eq 9)

Construction No. 2: U_i = 1/14.43 = 0.069; U_s = 0.128. With framing unchanged, U_{av} = 0.8(0.069) + 0.2(0.128) = 0.081

TABLE VI. AIR EXCHANGES IN RESIDENCES FOR TYPICAL DESIGN CONDITIONS*
(Adapted from Tables 7.11A and 7.11B, Cooling and Heating Load Calculation Manual, ASHRAE, 1979, Page 7.23)

Type Room	Changes/Hour
Room w/o windows or exterior doors	0.5
Rooms with windows or exterior doors on one side	1.0
Rooms with windows or exterior doors on two sides	1.5
Rooms with windows or exterior doors on three sides	2.0
Entrance halls	2.0

*Use 2/3 of tabulated values for weatherstripped windows or storm sashes.

TABLE VII. RECOMMENDED VENTILATION AIR VOLUME FOR SINGLE FAMILY RESIDENCES
(Adapted from Cooling and Heating Load Calculation Manual, ASHRAE, 1977, Page 5.12)

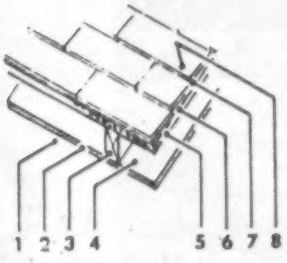
Room	Ventilation Air Per Occupant	
	Minimum (cu ft/min)	Recommended (cu ft/min)
General living areas; bedroom, utility areas	5.0	7.0-10.0
Kitchens, bathrooms	20.0	30.0-50.0

TABLE VIII. SOL-AIR TEMPERATURES FOR JULY 21 AT 40°N LATITUDE
(Adapted from Fundamentals Handboook, 1977, ASHRAE, Page 25.5)

Time	Air Temp.	Light Surfaces					Dark Surfaces				
		N	E	S	W	HOR	N	E	S	W	HOR
4	74	74	74	74	74	67	74	74	74	74	67
8	77	82	114	83	81	96	87	151	89	96	122
12	90	96	97	112	97	127	103	104	134	104	172
16	94	99	98	100	131	113	104	103	106	168	139
20	85	85	85	85	85	78	85	85	85	85	85
24	77	77	77	77	77	70	77	77	77	77	70
Avg.	83	86	91	89	91	91	89	100	85	100	107

TABLE IX. COEFFICIENTS OF HEAT TRANSFER (U) THROUGH PITCHED ROOFS[a]
(Reference, Cooling and Heating Load Calculation Manual, ASHRAE, 1979, Page 3.11)

Coefficients are expressed in Btu per (hour) (square foot) (degree Fahrenheit difference in temperature between the air on the two sides), and are based on an outside wind velocity of 15 mph for heat heat flow upward and 7.5 mph for heat flow downward. The Heat Capacity Units are Btu/ft²·°F.



Find U_{av} for same Construction 2 with Heat Flow Down (Summer Conditions)

Construction 1 (Heat Flow Up) (Reflective Air Space)	1 Resistance (R) Between Rafters	1 Resistance (R) At Rafters	2 Resistance (R) Between Rafters	2 Resistance (R) At Rafters	1 Heat Capacity Between Rafters	2 Heat Capacity Between Rafters
1. Inside surface (still air)	0.62	0.62	0.76	0.76	—	—
2. Gypsum wallboard 0.5 in., foil backed	0.45	0.45	0.45	0.45	0.54	0.54
3. Nominal 2-in. × 4-in. ceiling rafter	—	4.38	—	4.38	—	—
4. 45 deg slope reflective air space, 3.5 in. (50 F mean, 30 deg F temperature difference)	2.17	—	4.33	—	—	—
5. Plywood sheathing, 0.625 in.	0.78	0.78	0.78	0.78	0.51	0.51
6. Felt building membrane	0.06	0.06	0.06	0.06	Neg	Neg
7. Asphalt shingle roofing	0.44	0.44	0.44	0.44	0.33	0.33
8. Outside surface (15 mph wind)	0.17	0.17	0.25**	0.25**	—	—
Total Thermal Resistance (R)	R_1=4.69	R_2=6.90	R_1=7.07	R_2=7.12	1.38	1.38

Construction No. 1: U_1=1/4.69= 0.213; U_2 = 1/6.90 = 0.145. With 10% framing (typical of 2-in. rafters @16-in. o.c.), U_{av}= 0.9 (0.213) + 0.1 (0.145) = 0.206

Construction No. 2: U_1=1/7.07 = 0.141; U_2 = 1/7.12 = 0.140. With framing unchanged, U_{av}= 0.9 (0.141) + 0.1 (0.140) = 0.141

Find U_{av} for same Construction 2 with Heat Flow Down (Summer Conditions)

Construction 1 (Heat Flow Up) (Non-Reflective Air Space)	3 Resistance (R) Between Rafters	3 Resistance (R) At Rafters	4 Resistance (R) Between Rafters	4 Resistance (R) At Rafters	3 Heat Capacity Between Rafters	4 Heat Capacity Between Rafters
1. Inside surface (still air)	0.62	0.62	0.76	0.76	—	—
2. Gypsum wallboard, 0.5 in.	0.45	0.45	0.45	0.45	0.54	0.54
3. Nominal 2-in. × 4-in. ceiling rafter	—	4.38	—	4.38	—	—
4. 45 deg slope, nonreflective air space, 3.5 in. (50 F mean; 10 deg F temperature difference)	0.96	—	0.90*	—	—	—
5. Plywood sheathing, 0.625 in.	0.78	0.78	0.78	0.78	0.51	0.51
6. Felt building membrane	0.06	0.06	0.06	0.06	Neg	Neg
7. Asphalt shingle roofing	0.44	0.44	0.44	0.44	0.33	0.33
8. Outside surface (15-mph wind)	0.17	0.17	0.25**	0.25**	—	—
Total Thermal Resistance (R)	R_1=3.48	R_2=6.90	R_1=3.64	R_2=7.12	1.38	1.38

Construction No. 3: U_1= 1/3.48 = 0.287; U_2 = 1/6.90 = 0.145. With 10% framing typical of 2-in. rafters @ 16-in. o.c.), U_{av}= 0.9 (0.287)+ 0.1 (0.145) = 0.273

Construction No. 4: U_1= 1/3.64 = 0.275; U_2 = 1/7.12 = 0.140. With framing unchanged, U_{av}= 0.9 (0.275) + 0.1 (0.140) = 0.262

Pitch of roof--45 deg.

*Air space value at 90 F mean, 10 deg F temperature difference.

**7.5-mph wind.

TABLE X. DETERMINATION OF U-VALUE RESULTING FROM ADDITION OF INSULATION TO THE TOTAL AREA[e] OF ANY GIVEN BUILDING SECTION (Adapted from Cooling and Heating Load Calculation Manual, ASHRAE, 1979, Table A3.1, Page A3.4)

GIVEN BLDG SECTION PROPERTY		ADDITIONAL THERMAL INSULATION, R[a, b], (hr·ft²·F)/Btu														
U	*R*	1	2	3	4	5	6	7	9	11	13	15	17	19	30	38
0.08	12.5	0.074	0.069	0.065	0.061	0.057	0.054	0.051	0.047	0.043	0.039	0.036	0.034	0.032	0.024	0.020
0.10	10.0	0.091	0.083	0.077	0.071	0.067	0.063	0.059	0.053	0.048	0.043	0.040	0.037	0.034	0.025	0.021
0.12	8.3	0.107	0.097	0.088	0.081	0.075	0.070	0.065	0.058	0.052	0.047	0.043	0.039	0.037	0.026	0.022
0.14	7.1	0.123	0.109	0.099	0.090	0.082	0.076	0.071	0.062	0.055	0.050	0.045	0.041	0.038	0.027	0.022
0.16	6.3	0.138	0.121	0.108	0.098	0.089	0.082	0.075	0.066	0.058	0.052	0.047	0.043	0.040	0.028	0.023
0.18	5.6	0.153	0.132	0.117	0.105	0.095	0.087	0.080	0.069	0.060	0.054	0.049	0.044	0.041	0.028	0.023
0.20	5.0	0.167	0.143	0.125	0.111	0.100	0.091	0.083	0.071	0.063	0.056	0.050	0.045	0.042	0.029	0.023
0.22	4.5	0.180	0.153	0.133	0.117	0.105	0.095	0.087	0.074	0.064	0.057	0.051	0.046	0.042	0.029	0.024
0.24	4.2	0.194	0.162	0.140	0.122	0.109	0.098	0.090	0.076	0.066	0.058	0.052	0.047	0.043	0.029	0.024
0.26	3.8	0.206	0.171	0.146	0.127	0.113	0.102	0.092	0.078	0.067	0.059	0.053	0.048	0.044	0.030	0.024
0.28	3.6	0.219	0.179	0.152	0.132	0.117	0.104	0.095	0.080	0.069	0.060	0.054	0.049	0.044	0.030	0.024
0.30	3.3	0.231	0.188	0.158	0.136	0.120	0.107	0.097	0.081	0.070	0.061	0.055	0.049	0.045	0.030	0.024
0.40	2.5	0.286	0.222	0.182	0.154	0.133	0.118	0.105	0.087	0.074	0.065	0.057	0.051	0.047	0.031	0.025
0.50	2.0	0.333	0.250	0.200	0.167	0.143	0.125	0.111	0.091	0.077	0.067	0.059	0.053	0.048	0.031	0.025
0.60	1.7	0.375	0.273	0.214	0.176	0.150	0.130	0.115	0.094	0.079	0.068	0.060	0.054	0.048	0.032	0.025
0.70	1.4	0.412	0.292	0.226	0.184	0.156	0.135	0.119	0.096	0.080	0.069	0.061	0.054	0.049	0.032	0.025

[a] If the insulation occupies a previously considered air space, an adjustment must be made in the given building section *R*-value.
[b] Adjust for furring or framing sections as necessary, separately.

TABLE XI. HEAT LOSS OF CONCRETE FLOORS AT OR NEAR GROUND LEVEL PER FOOT OF EXPOSED EDGE (LESS THAN 3 FT BELOW GRADE) (Reference, Cooling and Heating Load Calculation Manual, ASHRAE, 1979, Table 7.9A, Page 7.22)

Outdoor Design Temperature, F	Heat Loss per Foot of Exposed Edge, Btu/(hr·ft)		
	R = 5.0 Edge Insulation	R = 2.5 Edge Insulation	No Edge Insulation[a]
20 to -30	50	60	75
-10 to -20	45	55	65
0 to -10	40	50	60
+10 to 0	35	45	55
+20 to +10	30	40	50

[a] This construction not recommended; shown for comparison only.

TABLE XII. OVERALL COEFFICIENTS OF HEAT TRANSMISSION (U-FACTOR) OF WINDOWS AND SKYLIGHTS, Btu/(hr·ft²·F)
(Reference, Cooling and Heating Load Calculation Manual, ASHRAE, 1979, Table 3.14A, Page 3.24)

Table 3.14A Overall Coefficients[a] of Heat Transmission (*U*-Factor) of Windows and Skylights, Btu/(hr · ft² · F)

Description	Exterior Vertical Panels				Exterior Horizontal Panels (Skylights)	
	Summer[**]		Winter[*]		Summer[**]	Winter[*]
	No Indoor Shade	Indoor Shade[***]	No Indoor Shade	Indoor Shade[***]		
Flat Glass[b]						
Single Glass[c]	1.04	0.81	1.10	0.83	0.83	1.23
Insulating Glass, Double[d]						
3/16 in. air space[e]	0.65	0.58	0.62	0.52	0.57	0.70
1/4 in. air space[e]	0.61	0.55	0.58	0.48	0.54	0.65
1/2 in. air space[e]	0.56	0.52	0.49	0.42	0.49	0.59
1/2 in. air space, low emittance coating[f]						
$\epsilon = 0.20$	0.38	0.37	0.32	0.30	0.36	0.48
$\epsilon = 0.40$	0.45	0.44	0.38	0.35	0.42	0.52
$\epsilon = 0.60$	0.51	0.48	0.43	0.38	0.46	0.56
Insulating Glass, Triple[d]						
1/4 in. air space[e]	0.44	0.40	0.39	0.31		
1/2 in. air space[e]	0.39	0.36	0.31	0.26		
Storm Windows						
1 in. to 4 in. air space[g]	0.50	0.48	0.50	0.42		
Plastic Bubbles[h]						
Single Walled					0.80	1.15
Double Walled					0.46	0.70

Table 3.14B Adjustment Factors for Various Window and Sliding Patio Door Types (Multiply *U*-Values in Part A by These Factors)

Description	Single Glass	Double or Triple Glass	Storm Windows
Windows			
All Glass[b]	1.00	1.00	1.00
Wood Sash; 80% Glass	0.90	0.95	0.90
Wood Sash; 60% Glass	0.80	0.85	0.80
Metal Sash; 80% Glass	1.00	1.20[m]	1.20[m]
Sliding Patio Doors			
Wood Frame	0.95	1.00	—
Metal Frame	1.00	1.10[m]	—

[a] See Table 3.14B for adjustments for various windows and sliding patio doors.
[b] Emittance of uncoated glass surface = 0.84.
[c] Double and triple refer to number of lights of glass.
[d] 0.125-in. glass.
[e] 0.25-in. glass
[f] Coating on either glass surface facing air space; all other glass surfaces uncoated.
[g] Window design: 0.25-in. glass, 0.125-in. glass, 0.25-in. glass.
[h] Refers to windows with negligible opaque areas.
[i] For heat flow up.
[j] For heat flow down.
[k] Based on area of opening, not total surface area.

[m] Values will be less than these when metal sash and frame incorporate thermal breaks. In some thermal break designs *U* values will be equal to or less than those for the glass. Window manufacturers should be consulted for specific data.

[*] 15 mph outdoor air velocity; 0 F outdoor air; 70 F inside air temp natural convection.

[**] 7.5 mph outdoor air velocity; 89 F outdoor air; 75 F inside air natural convection; solar radiation 248.3 Btu/(hr · ft²)

[***] Values apply to tightly closed venetian and vertical blinds, draperies, and roller shades.

The reciprocal of the above *U*-factors is the thermal resistance, *R*, for each type of glazing. If tightly drawn drapes (heavy close weave), closed Venetian blinds, or closely fitted roller shades are used internally, the additional *R* is approximately 0.29 (hr · ft² · F)/ Btu. If miniature louvered solar screens are used in close proximity to the outer fenestration surface, the additional *R* is approximately 0.24 (hr · ft² · F)/ Btu.

TABLE XIII. COEFFICIENTS OF TRANSMISSION (U) THROUGH DOORS, Btu per ($hr \cdot ft^2 \cdot F$)

	Winter			Summer
	Solid Wood,	Storm Door[b]		
Thickness[a]	No Storm Door	Wood	Metal	No Storm Door
1-in.	0.64	0.30	0.39	0.61
1.25-in.	0.55	0.28	0.34	0.53
1.5-in.	0.49	0.27	0.33	0.47
2-in.	0.43	0.24	0.29	0.42
	Steel Door			
1.75 in.				
A[c]	0.59	—	—	0.58
B[d]	0.19	—	—	0.18
C[e]	0.47	—	—	0.46

[a]Nominal thickness.
[b]Values for wood storm doors are for approximately 50% glass; for metal storm door values apply for any percent of glass.
[c]A = Mineral fiber core (2 lb/ft^3).
[d]B = Solid urethane foam core with thermal break.
[e]C = Solid polystyrene core with thermal break.

TABLE XIV. CORRECTION FACTORS FOR HEAT LOSS VS. DEGREE DAYS INTERIM FACTOR C_Da (Reference Systems Handbook, ASHRAE, 1976, Page 43.8)

Outdoor Design Temp, F	-20	-10	0	+10	+20
Factor C_D	0.57	0.64	0.71	0.79	0.89

[a]The multipliers in Table 2 which are high for mild climates and low for cold regions, are not in error as might appear. For equivalent buildings, those in warm climates have a greater portion of their heating requirements on days when the *mean* temperature is close to 65 F, and thus the actual heat loss is not reflected.

TABLE XV. PART LOAD CORRECTION FACTOR (C_F) FOR FUEL-FIRED EQUIPMENT (Reference, Systems Handbook, ASHRAE, 1976, Page 43.8)

Percent oversizing	0	20	40	60	80
Factor C_F	1.36	1.56	1.79	2.04	2.32

[a]Because equipment performance at extremely low loads is highly variable, it is strongly recommended that the values in Table 3 not be extrapolated.

TABLE XVI. DESIGN EQUIVALENT TEMPERATURE DIFFERENCES (ETD) FOR WALLS, CEILINGS AND FLOORS
(Reference, Cooling and Heating Load Calculation Manual, ASHRAE, 1979, Table 7.8, Page 7.22)

Design Temperature, deg F	85		90			95			100		105	110
Daily Temperature Range [a]	L	M	L	M	H	L	M	H	M	H	H	H
WALLS AND DOORS												
1. Frame and veneer-on-frame	17.6	13.6	22.6	18.6	13.6	27.6	23.6	18.6	28.6	23.6	28.6	33.6
2. Masonry walls, 8-in. block or brick	10.3	6.3	15.3	11.3	6.3	20.3	16.3	11.3	21.3	16.3	21.3	26.3
3. Partitions, frame	9.0	5.0	14.0	10.0	5.0	19.0	15.0	10.0	20.0	15.0	20.0	25.0
masonry	2.5	0	7.5	3.5	0	12.5	8.5	3.5	13.5	8.5	13.5	18.5
4. Wood doors	17.6	13.6	22.6	18.6	13.6	27.6	23.6	18.6	28.6	23.6	28.6	33.6
CEILINGS AND ROOFS [b]												
1. Ceilings under naturally vented attic or vented flat roof—dark	38.0	34.0	43.0	39.0	34.0	48.0	44.0	39.0	49.0	44.0	49.0	54.0
—light	30.0	26.0	35.0	31.0	26.0	40.0	36.0	31.0	41.0	36.0	41.0	46.0
2. Built-up roof, no ceiling—dark	38.0	34.0	43.0	39.0	34.0	48.0	44.0	39.0	49.0	44.0	49.0	54.0
—light	30.0	26.0	35.0	31.0	26.0	40.0	36.0	31.0	41.0	36.0	41.0	46.0
3. Ceilings under unconditioned rooms	9.0	5.0	14.0	10.0	5.0	19.0	15.0	10.0	20.0	15.0	20.0	25.0
FLOORS												
1: Over unconditioned rooms	9.0	5.0	14.0	10.0	5.0	19.0	15.0	10.0	20.0	15.0	20.0	25.0
2. Over basement, enclosed crawl space or concrete slab on ground	0	0	0	0	0	0	0	0	0	0	0	0
3. Over open crawl space	9.0	5.0	14.0	10.0	5.0	19.0	15.0	10.0	20.0	15.0	20.0	25.0

[a] Daily Temperature Range
L (Low) Calculation Value: 12 deg F. Applicable Range: Less than 15 deg F.
M (Medium) Calculation Value: 20 deg F. Applicable Range: 15 to 25 deg F.
H (High) Calculation Value: 30 deg F. Applicable Range: More than 25 deg F.

[b] Ceiling and Roofs: For roofs in shade, 18-hr average = 11 deg temperature differential. At 90 deg F design and medium daily range, equivalent temperature differential for light-colored roof equals $11 + (0.71)(39 - 11) = 31$ deg F.

TABLE XVII. DESIGN COOLING LOAD FACTORS THROUGH GLASS (ETD)
(Reference, Cooling and Heating Load Calculation Manual, ASHRAE, 1979, Table 7.6, Page 7.21)

Outdoor	Regular Single Glass						Regular Double Glass						Heat Absorbing Double Glass						Clear Triple Glass		
Design Temp	85	90	95	100	105	110	85	90	95	100	105	110	85	90	95	100	105	110	85	90	95
No Awnings or inside Shading																					
North	23	27	31	35	39	44	19	21	24	26	28	30	12	14	17	19	21	23	17	19	20
NE and NW	56	60	64	68	72	77	46	48	51	53	55	57	27	29	32	34	36	38	42	43	44
East and West	81	85	89	93	97	102	68	70	73	75	77	79	42	44	47	49	51	53	62	63	64
SE and SW	70	74	78	82	86	91	59	61	64	66	68	70	35	37	40	42	44	46	53	55	56
South	40	44	48	52	56	51	33	35	38	40	42	44	19	21	24	26	28	30	30	31	33
Horiz. Skylight	160	164	168	172	176	181	139	141	144	146	148	150	89	91	94	96	98	100	126	127	129
Draperies or Venetian Blinds																					
North	15	19	23	27	31	36	12	14	17	19	21	23	9	11	14	16	18	20	11	12	14
NE and NW	32	36	40	44	48	53	27	29	32	34	36	38	20	22	25	27	29	31	24	26	27
East and West	48	52	56	60	64	69	42	44	47	49	51	53	30	32	35	37	39	41	38	39	41
SE and SW	40	44	48	52	56	61	35	37	40	42	44	46	24	26	29	31	33	35	32	33	34
South	23	27	31	35	39	44	20	22	25	27	29	31	15	17	20	22	24	26	18	19	21
Roller Shades Half-Drawn																					
North	18	22	26	30	34	39	15	17	20	22	24	26	10	12	15	17	19	21	13	14	15
NE and NW	40	44	48	52	56	61	38	40	43	45	47	49	24	26	29	31	33	35	34	35	35
East and West	61	65	69	73	77	82	54	56	59	61	63	65	35	37	40	42	44	46	49	49	50
SE and SW	52	56	60	64	68	73	46	48	51	53	55	57	30	32	35	37	39	41	41	42	43
South	29	33	37	41	45	50	27	29	32	34	36	38	18	20	23	25	27	29	25	26	26
Awnings																					
North	20	24	28	32	36	41	13	15	18	20	22	24	10	12	15	17	19	21	11	12	13
NE and NW	21	25	29	33	37	42	14	16	19	21	23	25	11	13	16	18	20	22	12	13	14
East and West	22	26	30	34	38	43	14	16	19	21	23	25	12	14	17	19	21	23	12	13	14
SE and SW	21	25	29	33	37	42	14	16	19	21	23	25	11	13	16	18	20	22	12	13	14
South	21	24	28	32	36	41	13	15	18	20	22	24	11	13	16	18	20	22	11	12	13

TABLE XVIII. SHADE LINE FACTORS FOR WINDOWS
(Reference, Cooling and Heating Load Calculation Manual, Table 7.7, Page 7.20)

Direction Window Faces	N Latitude, Deg						
	25	30	35	40	45	50	55
E/W	0.8	0.8	0.8	0.8	0.8	0.8	0.8
SE/SW	1.9	1.6	1.4	1.3	1.1	1.0	0.9
S	10.1	5.4	3.6	2.6	2.0	1.7	1.4

Note: Distance shadow line falls below the edge of the overhang equals shade line factor multiplied by width of overhang. Values are averages for 5 hr of greatest solar intensity on August 1.

TABLE XIX. SENSIBLE COOLING LOAD DUE TO INFILTRATION AND VENTILATION
(Reference, Fundamentals Handbook, ASHRAE, 1977, Table 38, Page 25.41)

Design Temperature, F	85	90	95	100	105	110
Infiltration, Btuh/ft^2 of gross exposed wall area	0.7	1.1	1.5	1.9	2.2	2.6
Mechanical ventilation, Btuh/cfm	11.0	16.0	22.0	27.0	32.0	38.0

TABLE XX. ESTIMATED EQUIVALENT RATED FULL-LOAD HOURS OF OPERATION FOR COOLING EQUIPMENT
(Reference, Systems Handbook, 1976, Table 5, Page 43.9)

Albuquerque, NM	800–2200	Indianapolis, IN	600–1600
Atlantic City, NJ	500–800	Little Rock, AR	1400–2400
Birmingham, AL	1200–2200	Minneapolis, MN	400–800
Boston, MA	400–1200	New Orleans, LA	1400–2800
Burlington, VT	200–600	New York, NY	500–1000
Charlotte, NC	700–1100	Newark, NJ	400–900
Chicago, IL	500–1000	Oklahoma City, OK	1100–2000
Cleveland, OH	400–800	Pittsburgh, PA	900–1200
Cincinnati, OH	1000–1500	Rapid City, SD	800–1000
Columbia, SC	1200–1400	St. Joseph, MO	1000–1600
Corpus Christi, TX	2000–2500	St. Petersburg, FL	1500–2700
Dallas, TX	1200–1600	San Diego, CA	800–1700
Denver, CO	400–800	Savannah, GA	1200–1400
Des Moines, IA	600–1000	Seattle, WA	400–1200
Detroit, MI	700–1000	Syracuse, NY	200–1000
Duluth, MN	300–500	Trenton, NJ	800–1000
El Paso, TX	1000–1400	Tulsa, OK	1500–2200
Honolulu, HI	1500–3500	Washington, DC	700–1200

TABLE XXI. UNIFORM PRESENT VALUE DISCOUNT FACTORS FOR ENERGY PRICE ESCALATION RATES FROM 0% TO 10% (BASED ON A 10% DISCOUNT RATE)
(Reference, Life Cycle Costing, NBS, 1978)

	Energy Price Escalation Rates										
Year	0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
1	0.9091	0.9182	0.9273	0.9364	0.9455	0.9546	0.9636	0.9727	0.9818	0.9909	1.0000
2	1.7355	1.7612	1.7871	1.8131	1.8393	1.8657	1.8921	1.9188	1.9457	1.9727	2.0000
3	2.4868	2.5353	2.5844	2.6340	2.6844	2.7354	2.7869	2.8391	2.8921	2.9456	3.0000
4	3.1698	3.2460	3.3237	3.4027	3.4834	3.5656	3.6492	3.7344	3.8213	3.9097	4.0000
5	3.7907	3.8986	4.0092	4.1225	4.2388	4.3581	4.4801	4.6053	4.7336	4.8650	5.0000
6	4.3552	4.4978	4.6449	4.7966	4.9531	5.1146	5.2808	5.4524	5.6294	5.8117	6.0000
7	4.8684	5.0480	5.2344	5.4278	5.6284	5.8367	6.0524	6.2765	6.5089	6.7498	7.0000
8	5.3449	5.5521	5.7810	6.0188	6.2669	6.5260	6.7959	7.0780	7.3723	7.6793	8.0000
9	5.7590	6.0159	6.2878	6.5722	6.8705	7.1839	7.5124	7.8577	8.2201	8.6004	9.0000
10	6.1445	6.4417	6.7577	7.0903	7.4411	7.8118	8.2028	8.6161	9.0524	9.5130	10.0000
11	6.4930	6.8328	7.1935	7.5755	7.9807	8.4113	8.8682	9.3539	9.8696	10.4174	11.0000
12	6.8137	7.1919	7.5977	8.0299	8.4909	8.9837	9.5095	10.0717	10.6722	11.3138	12.0000
13	7.1034	7.5216	7.9725	8.4553	8.9733	9.5300	10.1274	10.7698	11.4601	12.2020	13.0000
14	7.3667	7.8243	8.3199	8.8536	9.4293	10.0513	10.7227	11.4487	12.2335	13.0819	14.0000
15	7.6061	8.1022	8.6421	9.2266	9.8604	10.5490	11.2964	12.1092	12.9929	13.9539	15.0000
16	7.8238	8.3574	8.9408	9.5758	10.2680	11.0240	11.8492	12.7516	13.7384	14.8178	16.0000
17	8.0216	8.5918	9.2179	9.9029	10.6535	11.4776	12.3821	13.3767	14.4706	15.6742	17.0000
18	8.2014	8.8069	9.4747	10.2090	11.0177	11.9103	12.8953	13.9844	15.1891	16.5223	18.0000
19	8.3649	9.0044	9.7129	10.4957	11.3622	12.3235	13.3900	14.5757	15.8947	17.3630	19.0000
20	8.5135	9.1857	9.9337	10.7641	11.6878	12.7178	13.8666	15.1507	16.5873	18.1958	20.0000
21	8.6486	9.3512	10.1385	11.0154	11.9957	13.0942	14.3259	15.7101	17.2674	19.0211	21.0000
22	8.7715	9.5042	10.3285	11.2509	12.2870	13.4537	14.7688	16.2546	17.9355	19.8394	22.0000
23	8.8832	9.6446	10.5046	11.4714	12.5623	13.7968	15.1955	16.7841	18.5913	20.6501	23.0000
24	8.9847	9.7735	10.6679	11.6777	12.8225	14.1241	15.6065	17.2989	19.2349	21.4531	24.0000
25	9.0770	9.8919	10.8193	11.8710	13.0686	14.4367	16.0026	17.7998	19.8670	22.2490	25.0000

TABLE XXII. COMPARISON OF BENEFIT/COST RATIOS FOR SEVERAL EXPECTED LIVES OF ENERGY CONSERVATION PRACTICES

(Discount Rate = 10%; Fuel Price Escalation Rate = 10%)

Expected Life (yrs)	Net Annual Savings (NAS) $	Present Worth Factor	Present Value of NAS	Benefit/Cost Ratio %
1	$445	1.0	$ 445	0.57
3		3.0	1335	1.71
5		5.0	2225	2.85
7		7.0	3115	3.99
10		10.0	4450	5.70
15		15.0	6675	8.55
20		20.0	8900	11.40
25		25.0	11125	14.24
(Discount Rate = 10%; Fuel Price Escalation Rate = 5%)				
1	$445	0.9546	$ 425	0.54
3		2.7354	1217	1.56
5		4.3581	1939	2.48
7		5.8367	2597	3.33
10		7.8118	3476	4.45
15		10.5490	4694	6.01
20		12.7178	5659	7.25
25		14.4367	6424	8.23

TABLE XXIII. COMPARISON OF BENEFIT/COST RATIOS FOR VARYING RATES OF ESCALATION IN FUEL COSTS

(Expected Life = 7 years; Discount Rate = 10%; First Cost = $781; NAS (1st year) = $445)

Annual Escalation Rate in Fuel Price (%)	Net Annual Savings $	Present Worth Factor	Present Value of NAS	Benefit/Cost Ratio %
0	$445	4.8684	2,166	2.77
2		5.2344	2,329	2.98
4		5.6285	2,505	3.21
6		6.0524	2,693	3.45
8		6.5089	2,896	3.71
10		7.0000	3,115	3.99

Bibliography

AIA Research Corporation, A Survey of Passive Solar Buildings, 1978.

AIA Research Corporation, Solar Dwelling Design Concepts, 1976.

Alliance to Save Energy, Energy Conservation Seminar Workbook, 1978.

American Plywood Association, All-Weather Wood Foundation System Vs. Conventional Poured Concrete.

ASAE, A Forum Approach to Housing Energy Conservation Programs, 1976.

ASHRAE, Cooling and Heating Load Calculation Manual, GRP 158, 1979.

ASHRAE, Energy Conservation in New Building Design, 90-75, 1975.

ASHRAE, Handbook of Fundamentals, 1977.

ASTM, Publications List, 1978.

Buyers Guide, The Service Reporter (Air Conditioning, Refrigeration, Heating and Ventilation), Box 745, Wheeling, IL 60090

Georgia Power Company, Handbook: Good Cents Home, 1977.

BIBLIOGRAPHY

AIT Research Corp. Solar Dwelling Design Concepts GPO Stock No. 023-000-00334-1, U. S. Government Printing Office, Washington, DC. 20402

Anderson, B. Solar Energy: Fundamentals in Building Disign. New York, NY 10036, McGraw Hill Co. 1977.

Badzinski, Stanley, Jr. Carpentry in Residential Construction. Englewood Cliffs, N. J. : Prentice-Hall, Inc., 1972.

Crowther, R. L. Sun Earth. Crowther/Solar Group, Denver, CO. 80206, 1976.

Dalzell, J. Ralph and Gilbert Townsend. Masonry Simplified, Vol. I, 3rd ed. Chicago: American Technical Society, 1973.

Davis, A. J. and Schubert, R. P.; Passive Energy Systems. P. O. Box 499, Blacksburg, VA 24060, 1977.

Durbahn, Walter E. Fundamentals of Carpentry, Vol. I, 4th ed. Chicago: American Technical Society, 1974.

Fisher, R. and Yanda, B.: Solar Greenhouse Design Construction and Operation, Santa Fe, NM, John Muir Publication, 1976.

Hudson Home Guides, Practical Guide to Solar Homes, Bantam Hudson Idea Books, New York, NY, 1977.

Leckie, Jim, Masters, Gil, Whitehouse, Harry, Young, Lily, Other Homes and Garbage, Sierra Club Books, San Francisco, CA., 1975.

Mazria, E. The Passive Solar Energy Book. Emmaus, PA 18049, Rodale Press, 1979.

Putnam, Robert. Concrete Block Construction, 3rd ed. Chicago: American Technical Society, 1973.

Solar 80 Project, Waterford School District Building Trades. Home Construction Project, Passive Solar Home Design. Waterford, Michigan, 1979-80.

USDOE, Energy Savings Through Automatic Thermostat Controls, 1977

USDOE, Home Energy Savers Workbook, 1977.

USDOE, How Business in Los Angeles Cut Energy Use by 20 Percent, 1976.

USDOE, Making the Most of Energy in Real Estate, 1978

USDOE, Minimum Energy Dwelling (MED) Workbook, 1977.

USDOE, National Energy Outlook, 1976.

USDOE, National Program Plan for Research and Development in Solar Heating and Cooling, 1976.

USDOE, Organization and Functions Fact Book, 1977.

USDOE, Project Retro-Tech, 1977.

USDOE, Solar Energy in America's Future, 1977.

USDOE, Survey of Cellulosic Insulation Materials, 1977.

USDOE, The National Energy Act, 1978.

USDOE, The Resource File: Practical Publications for Energy Management, 1978.

USDOE, Tips for Energy Savers, 1975.

All USDOE Publications available from Washington, DC 20402 Government Printing Office, Superintendent of Documents.

Wagner, Willis H. Modern Carpentry. South Holland, IL: The Goodheart-Willcox Co., Inc., 1969.

Watson, D. Designing and Building a Solar House, Charlotte, VT 05445, Garden Way Publishing, 1977.